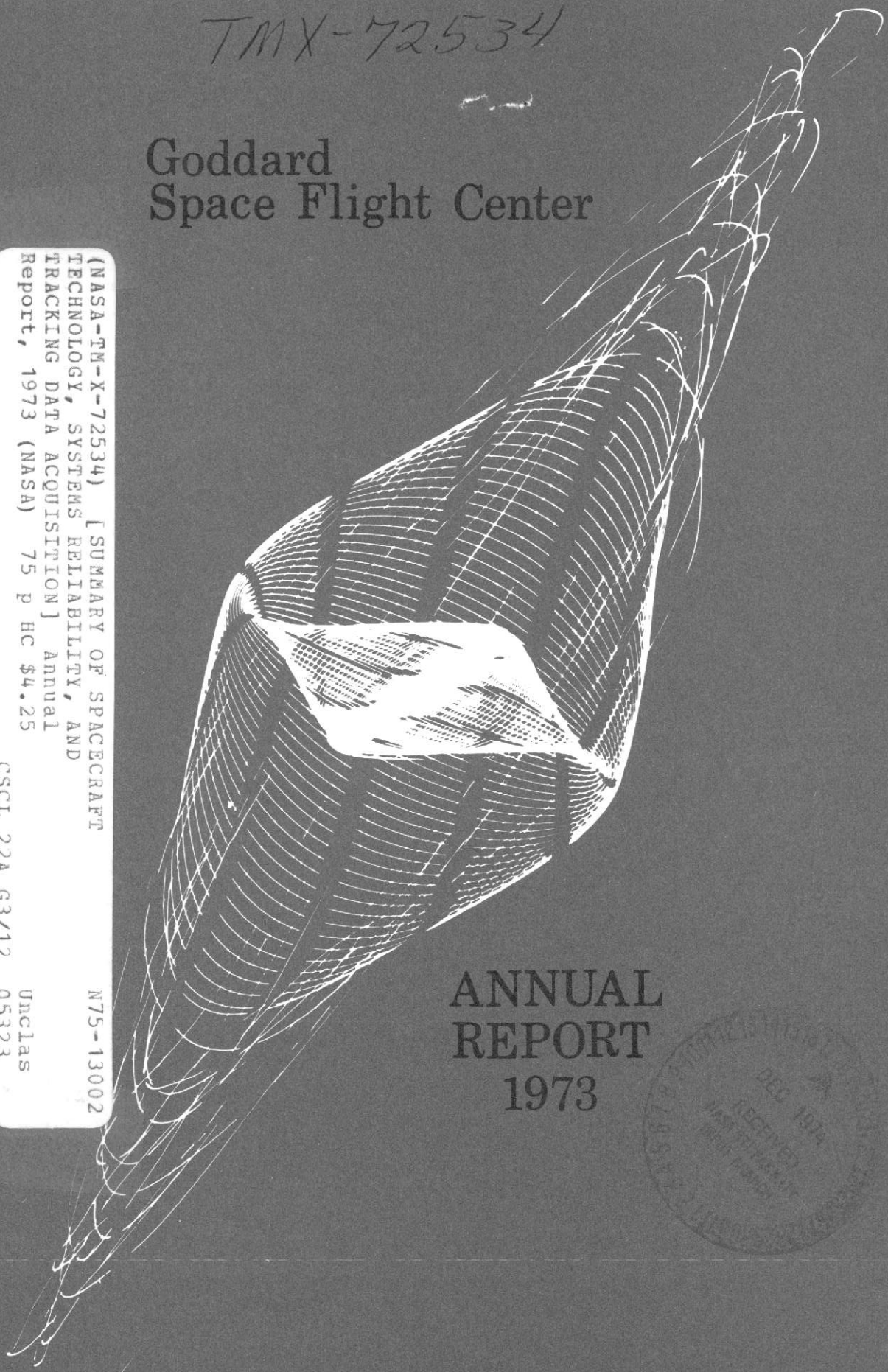
TMX-72534

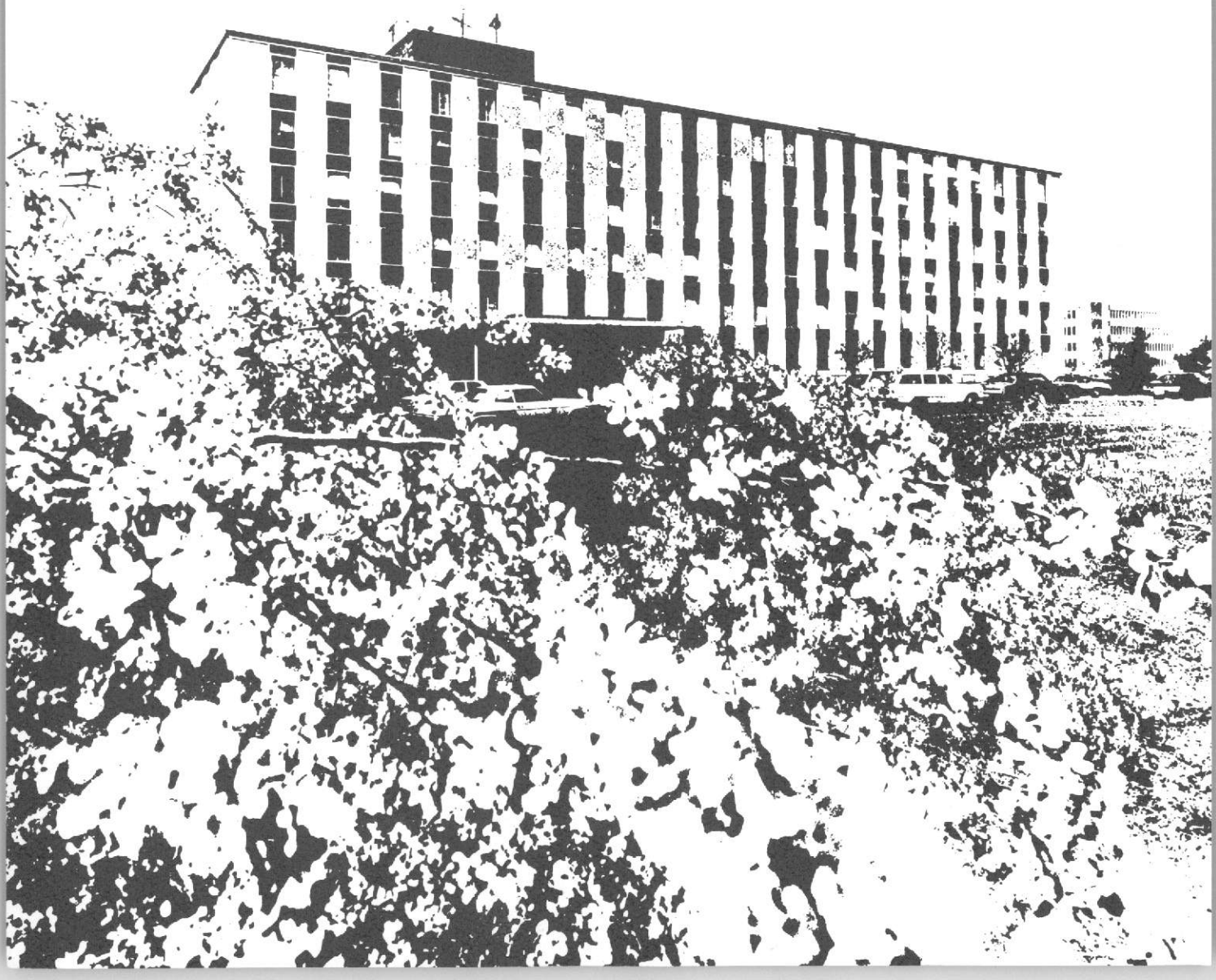
Goddard Space Flight Center



ANNUAL REPORT 1973

The cover photo is a tracing of the pattern ascribed by the tip of an extended section of one of the four 750-foot Radio Astronomy Explorer satellite booms as it is allowed, after deflection, to come to rest in a vacuum.

CONTENTS



Goddard Space Flight Center

ANNUAL REPORT 1973

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND 20771

PROJECTED FLIGHT PROJECTS (1974-1981)

NASA

1974	1975	1976	1977	1978	1979	1980	1981
ERTS-B ATS-F NIMBUS-F	OSO-I		ERTS-C NIMBUS-G	SMM	EOS TDRS	SMM ↓	SMM EOS SEOS
SMS-A SMS-B	AE-D AE-E	IUE	ISEE TIROS-N	ISEE AASIR	LPO AE-F	ASP AE-S	ASP ASP LST
	SAS-C		HEAO-A AEM	HEAO-B AEM GRE	AEM IRE LBE IAE	AEM TBD	AEM TBD

INTERNATIONAL

HELIOS-A ANS AEROS UK-5 SAN MARCO		HELIOS-B			CP		

REIMBURSABLE

ITOS-G	ITOS-H GOES-A	ITOS GOES-B GOES-C	ITOS	TIROS-N TIROS-N	TIROS-N GOES-D ERS	TIROS-N GOES-E GOES-F ERS TDRS TDRS	TIROS-N ERS TDRS

1974	1975	1976	1977	1978	1979	1980	1981

DIRECTOR'S MESSAGE

The hectic early years of space exploration have given way to an era of careful selection of goals, long range planning, austerity, and hard-fought priorities for competing objectives. Many benefits can come from the preparation of an Annual Report. The greatest value for managers lies in the perspective which results from evaluating the past and projecting the future.

For the public, the report provides a comprehensive view of what we do. For employees and others who know us, it makes available a more balanced picture of our activities and accomplishments. For all, it clarifies our ability to confront the future.

Dr. J. F. Clark and Deputy Director D. P. Hearth

The achievements of 1973 explained in this report range over a wide variety of disciplines and activities. This is natural, for Goddard is an extremely diversified space flight center; we are engaged in space science, earth science, space applications, project management, technology, and tracking and data operations. To strengthen these disciplines, the Center completed a major reorganization this year. We drew together many scattered groups and created the Applications Directorate, thus focusing our resources in this expanding area so vital to the practical utilization of space flight for public benefit. We also restructured the Engineering Directorate to concentrate in one place our space systems engineering support activities. A third managerial innovation was the provision of additional direct support for flight project managers: deputies for both technical and resources. The intent is to emphasize that today, there must be equal emphasis on business management and technical management.

The eight-year flight schedule on the opposite page reflects intended and potential spacecraft missions. Those lightly shaded are being studied by the Goddard staff, while those darkly shaded are in preliminary planning stages. We have the capability to carry out each of these missions which progress to approved and funded status. We achieved what is described in this report. While we look toward new missions, successful implementation of our many current commitments will provide the basis for a strong future. We will make the history for future reports.

Space has an important role in the future of our nation. Goddard has an important role in the future of our space program.

John F. Clark

SCIENCE

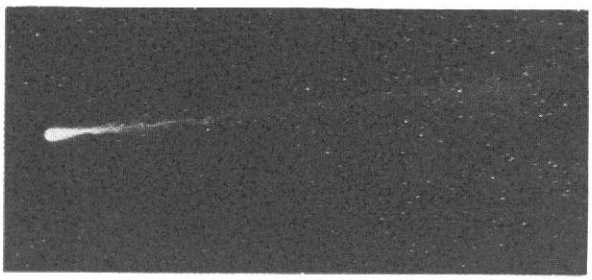
During calendar year 1973, significant amounts of data on various space science disciplines were obtained from many spacecraft, six of which were launched in 1973 (Pioneer 11, Skylab, RAE-B, IMP-8, Mariner 10, and AE-C). By discipline, the principle U.S. spacecraft acquiring data were:

Stellar Ultra-Violet	Copernicus (OAO-3), Skylab (ATM)
Stellar X-rays	IMPs-7 & 8, OSO-7, Skylab, VELA-5B, and UHURU (SAS-1)
Stellar Gamma Rays	IMP-6, SAS-2, VELAs-5A, -6A, & -6B
Solar Radiation	AE-C, IMPs-7 & 8, OSO-7, OV-5-6, Skylab, Solrad-10, VELAs-5B, -6A, & -6B
Radio Astronomy	IMP-6, RAE-B
Particles/Fields	Mariner 10, Pioneers 10 & 11 (Deep Space);
(Interplanetary, Galactic, Solar)	IMPs-6, -7, & -8, VELAs-5B, -6A, & 6B, OV-5 & -6 (geocentric); and ALSEP packages (lunar surfaces)
(Magnetosphere)	ATS-5, S^3 IMPs-6, -7, & -8, VELAs-5B, -6A, & -6B, OV-5 & -6, AE-C, ISIS-1 & -2, S71-2, and S72-1
(Aurora)	AE-C, ISIS-1 & -2, S71-2, and S72-1
Upper Atmosphere	AE-C, ISIS-1 & -2, NIMBUS-5, NOAA-1 & 2

In 1973 the GSFC science program participants continued with studies of major importance. Some of the space science activities and findings in various disciplines are briefly described in the following paragraphs.

COMET KOHOUTEK

In order to study the origin and nature of comets and the physical processes affecting



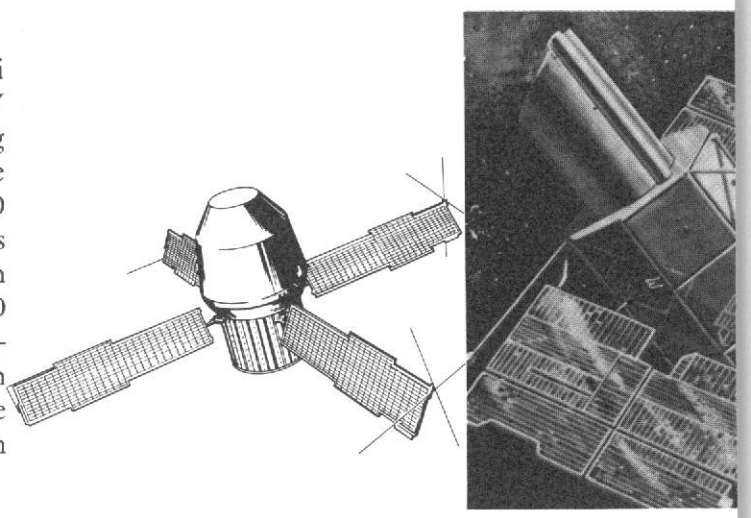
them, GSFC coordinated a large scale effort to observe the composition and evolution of the various components (coma, tail, etc.) of the Comet Kohoutek during its passage through the inner solar system. Among the spacecraft mobilized for this effort were Skylab, Mariner 10, Copernicus (OAO-3), and OSO-7. A series of rocket and aircraft experiments were carried out, as were a series of ground-based optical, radio, and infrared observations. Important preliminary results already obtained by late December 1973 when the comet passed perihelion were:

- Direct proof for the existence of water in comets as predicted by the "dirty snowball" theory;
- Detection of the molecules methyl cyanide and hydrogen cyanide in accord with the theory that comets formed not in the planetary system but rather in the Oort cloud, far beyond the present orbit of Pluto;
- Observation of an unusual ultraviolet "tapered tail," possibly indicating the presence of carbon ions, with a special instrument on Skylab; and
- Discovery by the Skylab astronauts of an "anti-tail" on December 29, 1973 when the comet was invisible from the ground.

Interpretation of the "anti-tail," which seemed to point toward the sun from the head of the comet, as viewed in perspective from Skylab, suggests that it was composed of tiny meteoroids shed from the nucleus of the comet. As the comet proceeded to the point of closest approach to the Earth in early 1974, further discoveries were anticipated.

STELLAR ULTRA-VIOLET

ζ Tauri UV Observations: The star ζ Tauri was studied using rocket and OAO-3 UV spectral scans. It was found that this exciting star is hotter than generally believed, the atmospheric parameters being $T_{eff} \approx 27{,}000$ °K and $\log g \approx 4.0$. The outer atmosphere is moving outward, possibly due to radiation pressure, with a velocity of about 80-100 km/sec. Finally, it was found that the populations of the various energy levels of a given ion in the shell surrounding the star are appropriate to a plasma with an electron temperature of 10,000 °K.



STELLAR GAMMA RAYS

Gamma Ray Symposium: The first international symposium devoted to gamma ray astrophysics was held at Goddard Space Flight Center from April 30 to May 2, 1973. The symposium was co-sponsored by NASA and the Division of Cosmic Physics of the American Physical Society (APS). Recent significant advances in observations and theory, cosmological and otherwise, of cosmic X-rays and cosmic and solar gamma rays were discussed. As a measure of the rapidity with which the field of gamma ray astrophysics has been evolving, the exciting cosmic gamma ray bursts which now occupy many experimenters' and theorists' efforts had not yet been discovered at the time of the symposium.

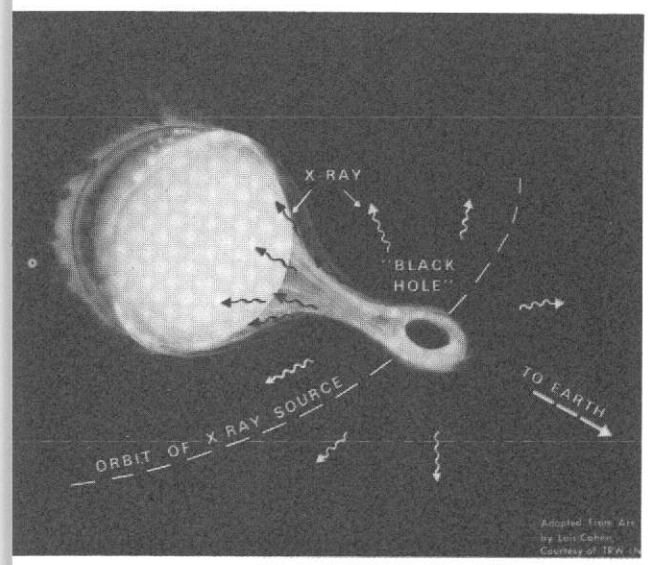
SAS-2 Diffuse Gamma Radiation: The GSFC experiment on the second Small Astronomy Satellite (SAS-B) consisted of a 32-deck, magnetic-core, digitized spark chamber gamma ray telescope designed to study celestial gamma radiation in the energy range above 30 MeV. A finite, diffuse flux of gamma rays with a steep energy spectrum in the energy region from 35 to 200 MeV has been observed. Combining this result with existing low energy gamma ray data yielded an energy spectrum which is not a simple power law in energy, as in the X-ray region, but which demonstrates a flattening at a few MeV followed by a rapid decrease. This spectrum is suggestive of a cosmological red-shifted π° decay spectrum, possibly resulting from matter-antimatter annihilation in the early phases of the *Big Bang* universe.

STELLAR X-RAY ASTRONOMY

The origin of the radio and hard X-ray emission from Sco X-1 was investigated. It was shown that the temperature distribution in the atmosphere of Sco X-1, as deduced from the X-ray observations, is consistent with supersonic expansion of its atmosphere and that this expansion, or wind, can maintain the magnetic field in the radio source and contribute to the ionization of the interstellar medium in the vicinity of the object.

Data from a GSFC rocket-borne experiment that measured the X-ray spectrum for the young supernova remnant Cas A were analyzed. The pronounced spectral peak observed at ~ 7keV characteristic of iron K line emission was used to obtain the first clear experimental evidence for copious ejection of subrelativistic cosmic ray iron nuclei by supernovae. It was concluded that if Cas A is representative of most supernovae, then the total quantity of iron so produced throughout the history of the galaxy would be comparable to the total now present in the galaxy.

This is a stylized concept of the symmetry of matter and antimatter in the universe. Depicted are two similar regions of the universe containing clusters of galaxies — — one consisting of matter and the other antimatter — — along with adjacent matter — antimatter regions. Based on gamma-ray data analyzed, Goddard scientists theorize that where matter and antimatter come together, nuclear annihilation occurs, resulting ultimately in the production of gamma-rays (symbolized by arrows), a by-product of the annihilation process. If future theoretical and experimental work confirms this evidence, it would establish, on a universal scale, a principle of symmetry which has become a cornerstone of modern physics.



The American Science and Engineering X-ray detector on the GSFC spacecraft UHURU (SAS-A) has measured X-ray emission from Cygnus X-1, apparently associated with an object much smaller than normal stellar dimensions; however, the mass of this object, as determined from optical data, must exceed about 6 solar masses. The inferred small size and large mass combine to suggest that this object is a black hole, an object with such a deep gravitational potential well that not even photons can escape from its immediate environs. Data from the OAO-3 X-ray detector support the black hole hypothesis. This first tentative identification of a black hole is of great astrophysical and cosmological significance.

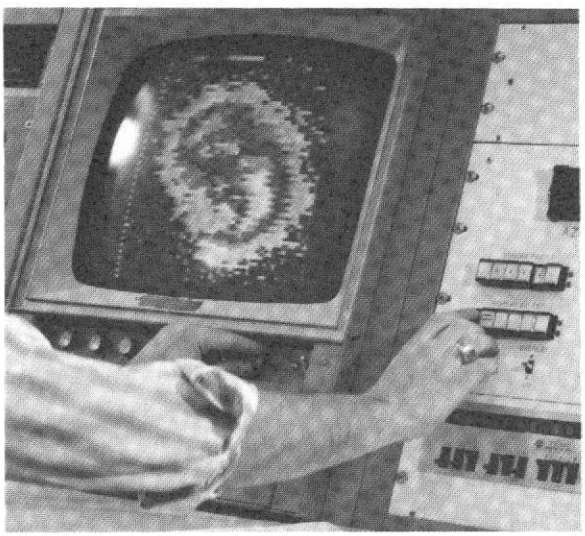
STELLAR THEORIES

Supernovae Formation: A new theory for the formation of supernovae has been developed at GSFC. This theory develops the mathematics that describe the physical conditions under which an evolving stellar system will be stable or non-stable. Only the stable case where the rotation period and the revolution period become equal has been well studied in the past. A class of non-stable orbits was found for which an orbiting dense white dwarf star will spiral into an evolving red giant star. The white dwarf then falls rapidly through the red giant's atmosphere to the core which is very similar to a white dwarf. The resulting collision could produce a supernova explosion that would leave a neutron star as a remnant. Previous models of single stars exploding did not leave neutron stars (pulsars) which are now known to exist. During the early phases of orbital decay the accretion of material onto the white dwarf will make it look like an X-ray star, and this may provide an explanation for certain classes of these objects.

Rotational Bursting of Small Celestial Bodies: Effects of Radiation Pressure: Solar radiation pressure can cause rotational bursting and eventual elimination from the solar system of small nonmagnetic bodies by a windmill effect. On the basis of experimentation it is estimated that actual bodies in space, such as nonmagnetic meteorites and tektites, will reach bursting speed in about 60,000 years. A mechanism and experimental results have been presented which can be used to explain the sparsity of population of sporadic meteoroids and micro-meteoroids relative to the amount of particles that would be expected from the dissolution of meteor streams.

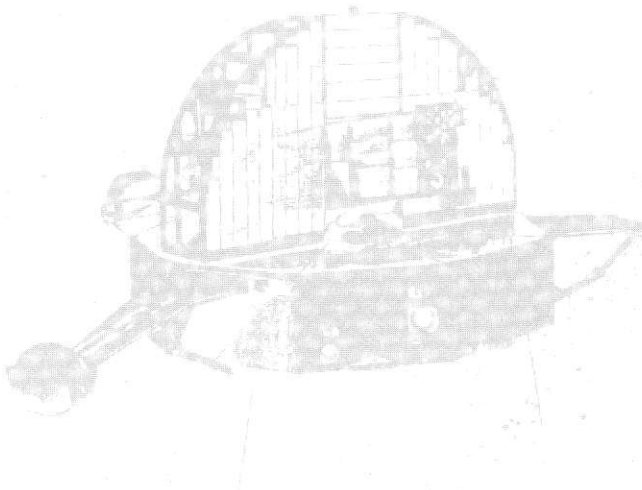
The mechanism itself is based on the interaction of radiation pressure, or light pressure, with the surface geometry of randomly shaped objects in heliocentric orbit. Experimental results using stones, tektites and a specially designed model have shown that arbitrarily shaped objects have what amounts to an effective moment arm when subjected to a directional pressure. A simple, though inadequate, analogy is the spinning of falling leaves. This effect is independent of the color of the object and is therefore, distinctly different from classical radiometric effects.

There are a number of applications of this result. For example, the Poynting-Robertson effect draws into the sun objects in solar orbit. The effect discussed here leads to the opposite conclusion, namely, that particles are swept out of the solar system. The time for the effects to act each vary in proportion to the radius of the particles and with the square of the distance from the sun, but the effect of rotational bursting will cause the particle to be swept out of the solar system in a few one hundredths of the time required for the Poynting-Robertson effect to act. The mechanism applies equally well to lunar ejecta which might be sent into orbit around the sun. This theory helps to understand why tektites appear in dense strewn fields in various places on the earth rather than randomly distributed.



SOLAR ASTRONOMY

High spectral- and spatial-resolution solar observations were made over a wide range of the electromagnetic spectrum during 1973 by the Apollo Telescope Mount (ATM) flown on Skylab and by OSO-7 (launched in 1971).



The principal new observation of the ATM X-ray telescope is a matrix of small bright emission regions distributed almost uniformly over the solar disk. These regions extend to the polar regions but are not found in "coronal holes." There is not yet a satisfactory explanation for these emission regions, and work will continue in 1974.

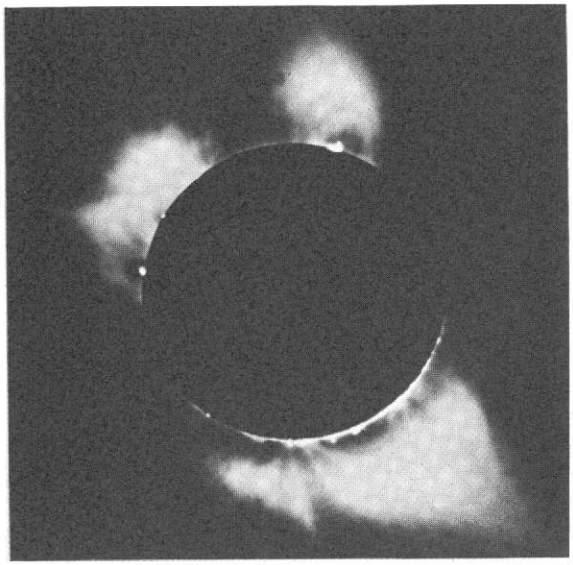
As an example of the continuing utility of older data, a 1973 GSFC study of OSO-1 and

The discovery of solar gamma-ray line emission by the University of New Hampshire experiment on OSO-7 has provided the first direct evidence for the presence of positrons and free neutrons in solar flares, such as the one shown in this "photo" of the sun, and demonstrates that nuclear reactions can take place even on the surface of the sun.

-3 EUV data and solar radio fluxes yielded a quantitative relation between 2800 MHz radio flux and the absolute EUV flux for several lines in the 150 Å to 400 Å region and the total flux of 81 intense lines. This study permits the continued monitoring of the ionosphere-affecting EUV flux by making radio observations on the ground.

Oscillations of the Solar Atmosphere: One of the most awe inspiring of nature's displays is a total solar eclipse, during which the moon passes directly in front of the sun, blocking from view the intense light that it radiates. Then, the sun can be seen to be surrounded by a white halo of light similar in brightness to the full moon. This halo or "crown" is known as the *solar corona*. For centuries, man has marveled at these spectacular events. Twentieth Century scientists have devoted their time to the study of the physical properties of the corona, and have found that it is made up of known atoms at a temperature approaching 2,000,000°C. This discovery is most puzzling. There is no way that the radiation emitted from the visible surface of the sun, the *photosphere*, with its 6,000°C temperature, can heat the coronal gasses to the observed temperature. There must be some other mechanism at work to do the job.

Just below the photosphere lies a deep layer of the sun known as the *convection zone*. In this zone, energy is carried from the deeper interior by mass motion of the gas. A blob of gas is heated at the bottom of the layer and becomes buoyant. The blob then rises rapidly to the top of the convection zone, where it radiates its heat into the more transparent upper layers, and sinks rapidly back into the zone. If one looks closely at the photosphere with a solar telescope, he will notice that the photosphere's surface is covered by a rice grain-like structure known as *granulation*. The individual granules are the tops of convective cells – fountains of gas rising through the convection zone. Individual granules are about 2000 km across. The rapid and powerful gas motions in the convection zone generate ordinary noise which propagates upward through the photosphere and intervening chromosphere into the corona. It was long thought that these noise waves would lose their energy in the corona, thus heating it up to the observed, high temperature; however, no simple, quantitative theory of the exact mechanism of heating had been developed up to the early 1960s.



Around 1960, solar physicists discovered sloshing waves with periods around five minutes in the photosphere and low chromosphere. The first reports indicated that the horizontal sizes of the sloshings were several thousand kilometers; that is, a few times larger than the granulation. It seemed reasonable to assume that the mechanical energy of the convection zone might be converted into the more orderly motion of these oscillations. But how? The astrophysicists have now worked out a simplified theory for the 5-minute oscillation – as the sloshing is called. The theory is simplified because the mathematical equations that describe the oscillation are very difficult to solve without several simplifying assumptions.

The theory shows that the photosphere and low chromosphere behave somewhat like a pendulum with a fixed length; that is, the layers have a specific period at which they will oscillate, naturally. When the atmospheric layers are buffered by the noise from the

convection zone, which contains waves of all periods, only the oscillations at the natural period of the photosphere will be excited. The theory shows, in addition, that waves in the photosphere with a 5-minute period will not propagate upward into the corona. These waves are trapped in the photosphere. At first this appears to be a disappointing result: the 5-minute period waves seem an ideal source for the coronal heating. Fortunately, the observations show that the atmosphere does not oscillate with one sharp period, but waves are present with a whole range of periods. The waves are strongest at the 5-minute period, and their amplitudes drop to half the maximum value at about a 4-minute period and at about a 6.5-minute period. The amplitudes continue to drop for periods shorter than 4 minutes and longer than 6.5 minutes.

The waves with periods of 4 minutes and shorter have enough energy to heat the solar corona. Furthermore, the theories say that these shorter period waves will propagate up into the corona. GSFC scientists feel, therefore, that there is strong theoretical evidence to support the contention that the shorter period waves heat the corona.

Because of the extreme importance of the 5-minute oscillation, scientists in Goddard's Laboratory for Solar Physics and Astrophysics have undertaken a wide range of studies of the properties of the waves, both from theoretical and observational viewpoints.

The possibility that the 5-minute oscillations are a form of non-radial pulsational mode of the entire sun has been investigated. One interesting apsect of this study is the possible influence of large solar flares on these pulsations. A flare is a tremendous burst of energy, released explosively in a localized region of the solar atmosphere, slightly above the photosphere. The energy released by the flare heats the underlying photospheric gasses which then undergo thermal expansion. The thermal expansion, in turn, gives the solar interior a kick which stimulates the entire sun to pulsate. This process is analogous to the "ringing" of the earth after a major earthquake. The pulsations of the sun might continue for a day or more.

Though it is clear that pulsations will be stimulated by flares, there are, in fact, other ways to start pulsations. It is fortunate that we can make this statement, since oscillations are observed to be present at all times, while major flares are relatively infrequent. When one investigates mechanisms, based on the flow of radiation through the gasses of the sun which can drive solar pulsations, it is found that for certain kinds of oscillations the pulsations will start of their own accord. The problem then reduces to discovering the modes in which the sun can oscillate. This problem was studied and it was found that there exist pulsation modes which are self-maintained and which have nearly 5-minute periods. It was shown, in addition, that the properties of these pulsations are in qualitative agreement with the observations. The horizontal scale size of the waves predicted by this theory can be very large, perhaps exceeding 50,000 km.

Interestingly, the observational research on the 5-minute oscillation reported between 1967 and 1973 support a horizontal scale much larger than the several thousand km reported around 1960. It now appears that a horizontal scale of roughly 30,000 km is consistent with the data. Such a scale size strongly supports GSFC results.

In late 1971, Orbiting Solar Observatory Number Seven (OSO-7) was launched into earth orbit. This satellite has provided solar scientists with an opportunity to study the sun at wavelengths which do not penetrate through the earth's protective atmosphere. A team of Goddard scientists flew an instrument on OSO-7 that was designed to study the Extreme Ultraviolet (EUV) (150 to 400 Angstrom) and X-ray emission from the sun. This EUV and X-ray emission originates in the corona and the so-called transition region between the chromosphere and the corona. It was decided to observe the EUV radiation at

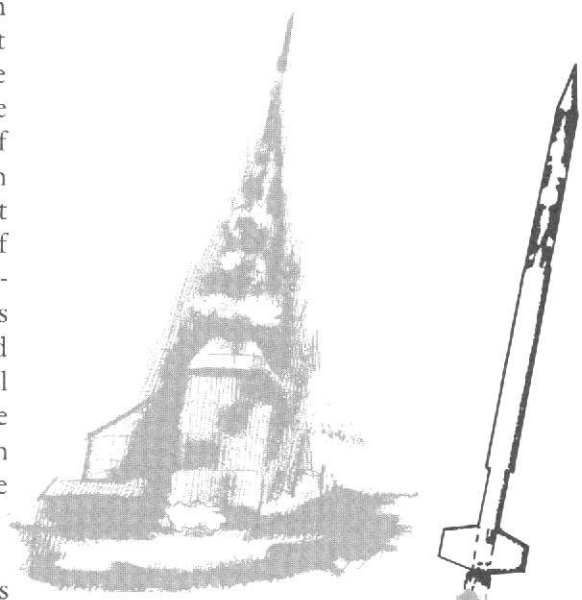
one wavelength from a small area (7500 by 15,000 km) near the center of the solar disk to see if oscillations could be detected. The data analysis remains tentative. However, it does appear that oscillations with periods around 3 minutes may exist in the transition region and corona. This result would, of course, be consistent with the theory that the short period waves of the 5-minute oscillation propagate into the corona and provide that heating. Similar observations in the visible part of the spectrum are difficult to make from the ground, so this study remains one of the first direct observations of oscillations in the corona. It must be added that the result has not gained widespread acceptance as of this writing, since there are puzzling, conflicting results from the Skylab/ATM solar studies carried out by scientists at the Harvard College Observatory. More sensitive statistical tests are even now being applied to the Goddard data in an attempt to obtain stronger evidence for the presence (or, to be fair, absence) of the waves.

Two related studies by scientists in Goddard's Laboratory for Solar Physics and Astrophysics will be mentioned to round out our story.

The possibility that very short-period sound waves (period around one-half minute) could become shock waves as they propagate up into the lower part of the chromosphere and thereby provide mechanical heating at that level, as other solar physicists have suggested, has been examined. It has been concluded on the basis of a rather involved theoretical calculation that there is, in fact, good reason to doubt that these short period waves alone can provide the heating required by observations. This suggests that, here again, the short-period component of the 5-minute oscillations might provide the heating of the low chromosphere.

Ground based observations of the radiation from the center of a sunspot have been made using Goddard facilities at the Sacramento Peak Observatory in New Mexico, and the data suggests the existence of oscillations with a 2.5-minute period in the sunspot.

The role of the 5-minute oscillations as a source of mechanical energy input to the chromosphere and corona remains an interesting and exciting topic for continuing research and undoubtedly will for some time to come.



Solar Physics Rocket Program: The Solar Physics rocket program in 1973 placed emphasis on support of the solar investigations on Skylab. To this end, solar scientists at four institutions were supported in the preparation of instrumentation for 6 to 8 Aerobee rocket flights, whose launches were to be timed to coincide with the appropriate Skylab observations. The rocket payloads consisted of various collimated crystal spectrometers, each adjusted to record with high resolution the X-ray emission over selected portions of the soft X-ray solar spectrum. These spectrometers were programmed to view the same regions on the sun being investigated by Skylab. It is anticipated that the temperature, density, and composition data obtained from the rocket spectroscopy flights will complement the detailed solar atmospheric structure data from the Skylab X-ray photographs in advancing our understanding of solar atmospheric structure and phenomena.

Solar Astrophysics: To study the flare-time origin of gamma rays, the propagation of neutrons in the solar atmosphere and their capture by hydrogen to form 2.2 MeV gamma rays have been investigated. A detailed Monte-Carlo calculation was used to determine whether a given neutron produced at the site of the flare would escape from the sun, decay at the sun, or be captured. The results of this calculation confirmed some previous assumptions. Some important quantitative differences have resulted: (1) not all downward moving neutrons are captured; (2) depending on the energy of the neutron and the position of the flare on the sun, a fraction of the 2.2 MeV gamma rays are Compton scattered and lost from the line. The expected time history of the solar atmosphere was also computed in detail.

PARTICLES AND FIELDS

Anomalous N,O Abundance: The finding of a new component in the primary galactic radiation was reported. Data from the GSFC/University of New Hampshire cosmic ray experiment on Pioneer 10 were used to measure the cosmic ray charge spectra from helium to oxygen down to energies of ~5 MeV/nuc during solar quiet times (March 1972 – March 1973). At energies down to 30 MeV the relative abundance measured for He:C:N:O was in excellent agreement with data at higher energies, i.e., up to 10 GeV. Below 30 MeV the helium spectrum remained essentially flat down to an energy of 5 MeV/nuc. The behavior of oxygen was strikingly different – it increased by a factor of 20 between 30 and 7 MeV/nuc; nitrogen displayed a similar increase. The carbon spectrum, however, decreased by a factor of 3 between 30 and 10 MeV/nuc. There was no significant increase in B, Ne, Mg, or Si. Thus, the data indicated a strong enhancement of 8-30 MeV/nuc oxygen and nitrogen relative to helium and carbon. The relative spatial and energy variation of He, C, N, and O differed markedly from that expected for solar particles, indicating that this newly observed feature is of galactic and not solar origin.

Supernova Cosmic Ray Source Model: A study of the origin of cosmic rays using results of a 1970 balloon flight was performed. From the observed charge composition of heavy primary cosmic radiation, a source composition was deduced, and it was then shown that the source composition agrees well with the composition predicted by a model which integrates the results of explosive carbon burning, explosive oxygen burning, and explosive silicon burning from massive stars, i.e., a supernova model for the origin of cosmic rays.

Jovian Trapped Particles: The GSFC/University of New Hampshire Pioneer 10 data from the Jovian encounter reveal a complex "magnetosphere" far different from that of earth. In discussing the observations, it is convenient to divide the Jovian magnetosphere into four regions:

(1) The region outside the Jovian magnetosphere in which large fluxes of MeV electrons and protons are observed to be coming from the magnetosphere: The MeV electrons are seen at distances of 1 AU away from Jupiter. Further analysis using IMP data shows that, in fact, Jovian electrons have been a major contributor to the 3–20 MeV electron flux measured at earth. A steady increase in the flux of > 0.5 MeV protons was also observed $\sim 5\,R_J$ before the crossing of the bow shock. These are probably also present at much greater distances from Jupiter but at a much smaller intensity than that displayed by the electrons.

(2) The outer Jovian magnetosphere: This region extends from the bow shock crossing ($109\,R_J$) to $\sim 50\,R_J$. The magnetic field is ~8–20γ and like the earth's tail is dominated by a neutral plasma sheath which is drawing the field lines outward. It is a region of quasi-trapping and diffusion. Both the electrons and protons show remarkably constant energy spectra, $E^{-\gamma}$ with $\gamma = 1.5$–2.0 and 4 respectively. This suggests that almost no acceleration occurs in this region. There are rapid changes in

flux and angular distributions. The high energy electrons (i.e. > 6 MeV) show a reasonable 10 hour periodicity as expected since the nominal magnetic latitude of the spacecraft should vary with the rotation period of the planet (~10 hrs). This is not nearly as significant for the protons or for the lower energy electrons. The changes in the proton and electron flux are frequently uncorrelated.

(3) The region between ~50 to 25 R_J is one of transition between the outer diffusion zone and the point where the field rigidly rotates with the planet. The proton energy spectra begin to change from a power law to an exponential energy form on a gradual scale suggesting that some acceleration is occurring. The angular distribution of the protons display large (up to ~ 70%) anisotropies and the hinging effect produced by the transition is strongly evident. The magnetic field is still changing rather slowly and it is not clear if the particles are stably trapped.

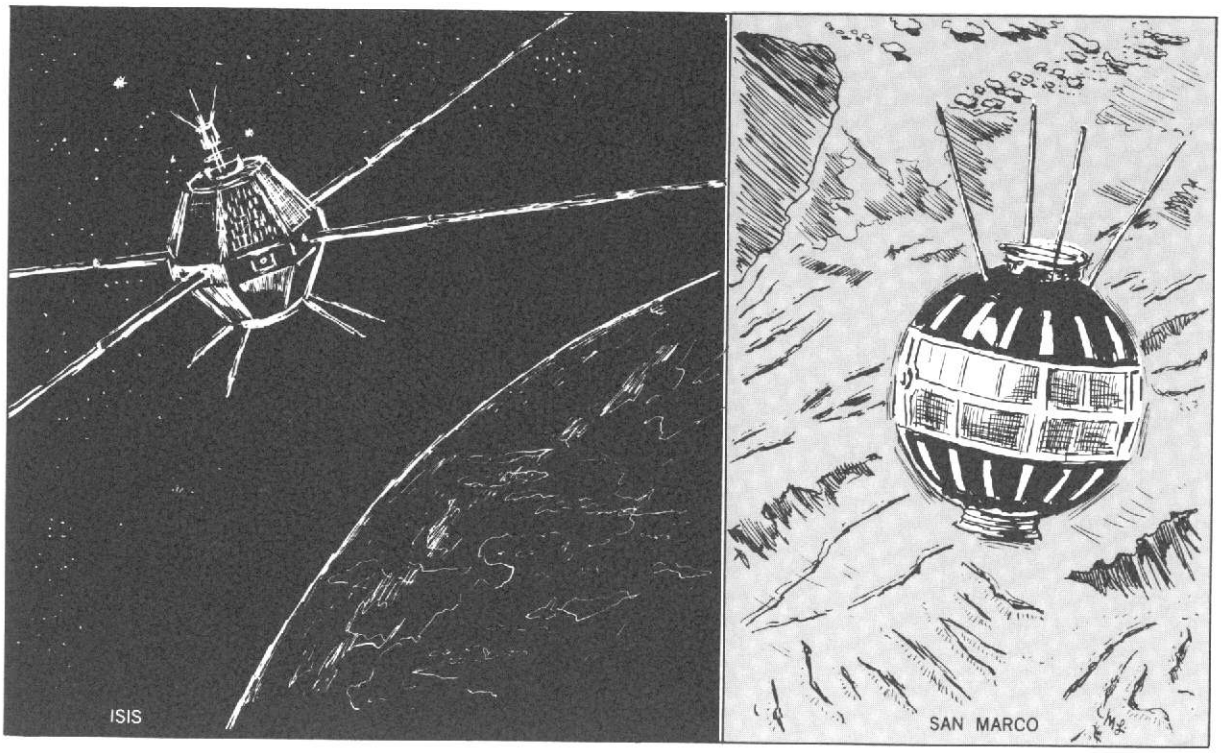
(4) Inside 25 R_J: The particle angular distributions indicate that the field lines are rigidly rotating with the planet within ~25 R_J, and this may mark the outer boundary for really stable trapping. This rapid decrease in the co-rotation anisotropy provides further evidence that the proton spectra are becoming increasingly flat below 1 MeV. At the outer edge of this region there is a significant increase in the 1-2 MeV proton component which climbs steadily until 6 R_J. Inside 6 R_J the proton component is strongly attenuated by the presence of the Jovian moon, Io. For example the 1-2 MeV component is reduced by a factor of 60 by Io absorption. The flux of all proton components then increases until ~ 0115 on December 4, when the spacecraft crossed the magnetic equator. The outbound trajectory near the dawn meridian was strikingly different from the inbound span in many respects. The peak fluxes are near the predicted magnetic equator; however, the dominant feature is the 10-hour periodicity which produces peak-to-valley ratios of as much as 5 decades for a 20° excursion in latitude. This implies that both electrons and protons are much more concentrated in the low latitude region on the outbound pass.

IONOSPHERE

The ISIS-2 Retarding Potential Analyzer yielded data during the solar disturbances of December 1971 and August 1972 which were analyzed in 1973 to study the behavior of the ionosphere/neutral atmosphere system in the mid and low latitude regions.

Several significant effects were observed: (1) a doubling of the characteristic nighttime ion temperature from about 900° to 2000° or more during the period of most disturbance; (2) an equatorward movement of the latitude of transition from H^+ to O^+ as the dominant ion; and (3) during the August 1972 storm, a significant change in composition at the equator, with the nighttime ionosphere becoming almost like a typical daytime equatorial ionosphere at 1400 km. Such a significant change implies an injection of energy comparable to the solar EUV heating, either directly or initially at higher latitude, and then propagating equatorward via the neutral upper atmosphere.

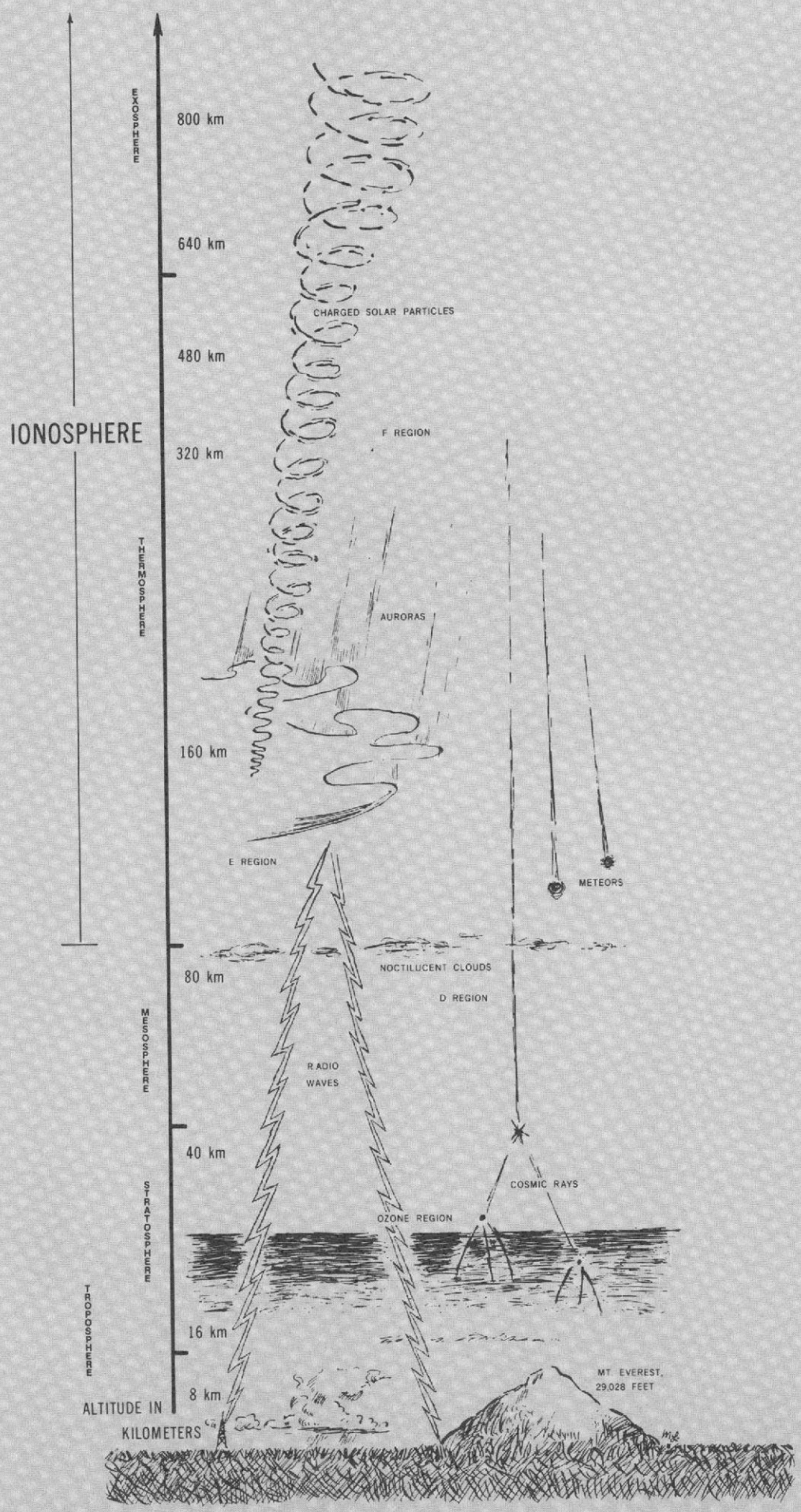
Further 1973 studies using both ISIS-2 data and 6300Å airglow maps for the December 1971 period showed that just after the peak of the December storm a red arc surrounded by an unusually high 6300Å background emission developed. Ion and electron temperatures, ion composition, and the particle precipitation data, as well as the red and green oxygen emissions and the electron density beneath the spacecraft were used to infer that near the peak of the storm the ionosphere in the region from the auroral zone to somewhat equatorward of the plasmapause was excited by a moderate level of energy conduction in the thermal plasma. Embedded within this region was the narrow (in latitude) red arc within which the energy conduction was several times larger, making possible the observed 800 Rayleigh red emission.



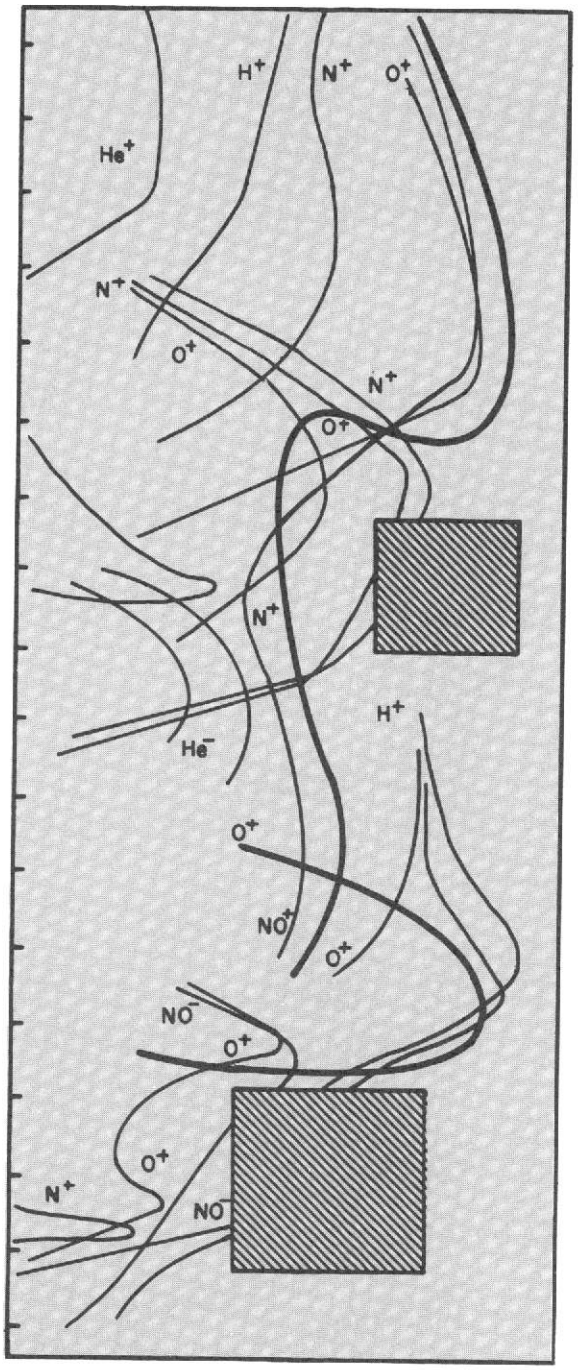
COMPOSITION OF THE UPPER ATMOSPHERE

Argon-A "Thermometer" of the Upper Atmosphere: It was established that atomic oxygen, which is usually the major neutral constituent in the region of satellite drag measurements, is subject to considerable variability with season, latitude, and levels of solar and geomagnetic activities in the altitude region of 120 km. The value of atomic oxygen as an indicator of thermospheric temperature is, therefore, questioned. OGO-6 neutral mass spectrometer measurements revealed that since molecular nitrogen is not subject to changes in eddy turbulence and is, therefore, relatively less variable near the turbopause, it is a better indicator of thermospheric temperature. Theoretical arguments, however, show that argon is much less variable because of changes in eddy diffusion and should be a better indicator of thermospheric temperature than either O or N_2. These arguments will be tested by making a comparison of the temperatures inferred from O, N_2, and Ar as measured from the AEROS Neutral Atmosphere Temperature Experiment.

San Marco-3 Neutral Mass Spectrometer Data: In order to study the complex behavior of the neutral thermospheric structure parameters at the equator during and following geomagnetic storms, it is necessary to define the equatorial composition during geomagnetically quiet time. To achieve this, San Marco-3 Neutral Mass Spectrometer data have been examined. Densities of N_2, He, Ar and total oxygen ($n[O] + n[O_2]$) have been examined at 220, 250, and 280 km altitudes to determine persistent diurnal variations. At 220 km altitude, for example, the N_2 and Ar variations are dominated by a diurnal component with maximum density occurring near 15.5 hours local time. The oxygen variations appear to be composed of three nearly equal variations with 24, 12, and 8 hour periods and maximum densities occurring near 10, 7, and 8 hours local time, respectively. The amplitudes of the oxygen variations are smaller than those of N_2 and Ar. The He variations are

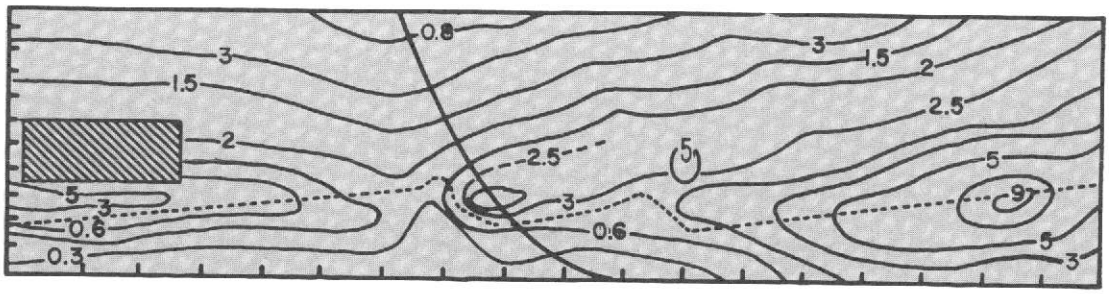

EXOSPHERE
800 km
640 km
CHARGED SOLAR PARTICLES
480 km
IONOSPHERE
F REGION
320 km
THERMOSPHERE
AURORAS
160 km
E REGION
METEORS
NOCTILUCENT CLOUDS
80 km
D REGION
MESOSPHERE
RADIO
WAVES
40 km
COSMIC RAYS
STRATOSPHERE
OZONE REGION
TROPOSPHERE
16 km
MT EVEREST,
29,028 FEET
8 km
ALTITUDE IN
KILOMETERS

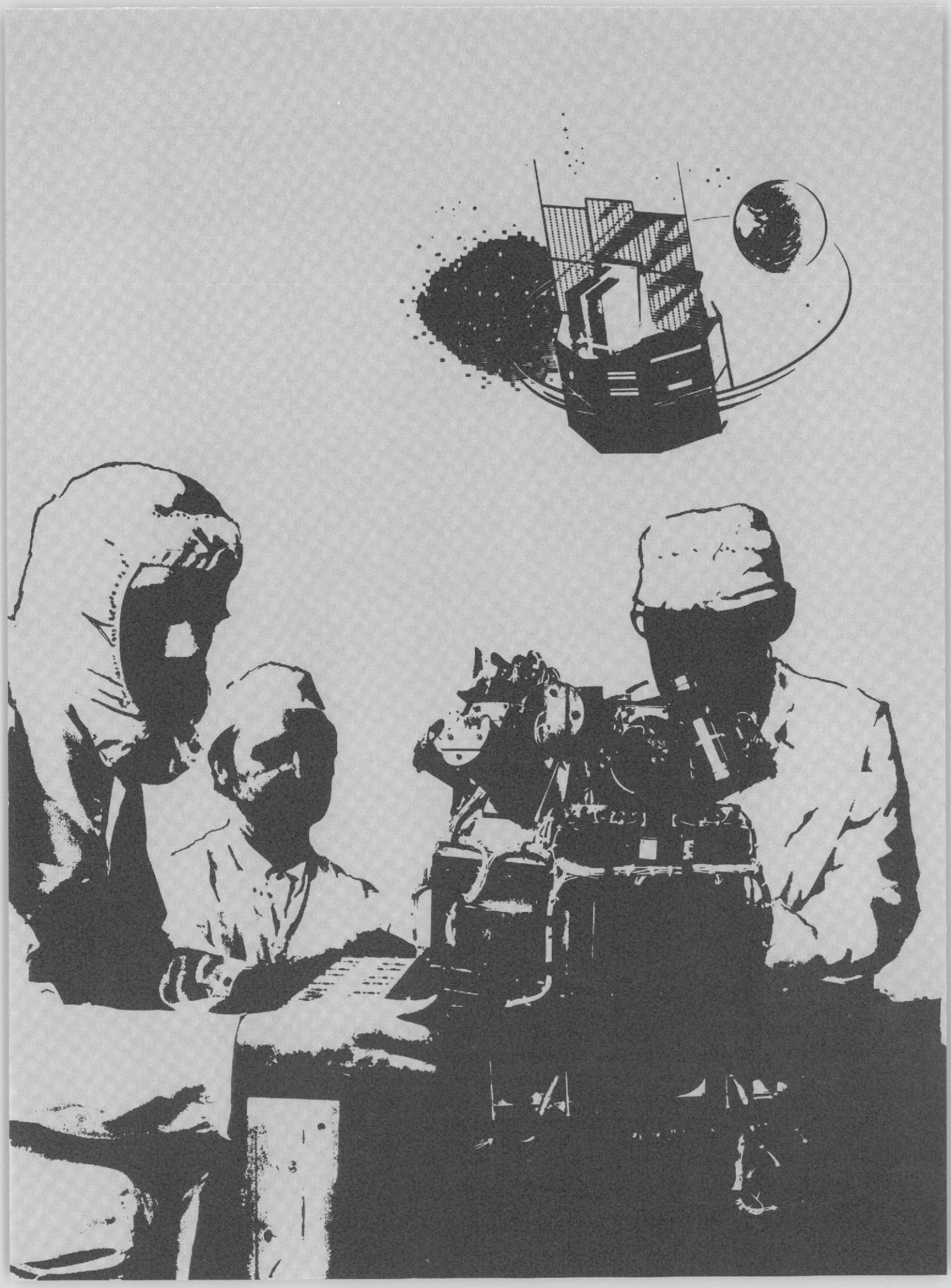
dominated by an unusually large diurnal component with maximum density occurring near 0730 hours local time. Mass density variations exhibit a diurnal variation amplitude between those of N_2 and oxygen with the density maximum occurring near 14 hours local time. Composition information down to the 137 km level was obtained during the one-week re-entry period. One interesting aspect of the data is that the departure of helium from diffusive equilibrium was in a direction which required a large upward flux.



Ion Composition: The latitudinal variation in ion composition of the summer mesosphere has been explored for the first time. Rocket 10.414 was launched from Kiruna, Sweden, (lat. 68°N) on August 2, 1973. Ion composition was measured by means of a quadrupole ion mass spectrometer. The D region was found to contain significant quantities of ions whose mass exceeded 100 AMU. These are presumably $H_3O^+ \cdot (H_2O^+)^{n>5}$. Other masses are present but are unidentified at present. In contrast, data obtained with similar instrumentation on June 30, 1973 at Wallops Island (lat. 38°N) indicate almost no ions of mass greater than 100 AMU. Since the mass sweep range was limited to 150 AMU for both instruments, the largest mass present in the high latitude summer D region is unknown. It certainly is in excess of 150 AMU.

The cause of the latitude difference may be the lower temperature which presumably exists at higher latitudes or a latitude difference in the water vapor mixing ratio. Noctilucent clouds were present during the launch of 10.414, and the ion composition data provide important clues concerning their origin.





FLIGHT PROJECTS

Calendar Year 1973 saw an active continuation of Goddard's flight project role in the discipline areas of planetary research, physics and astronomy, communications, and earth observations. In addition to the numerous Goddard-developed satellites currently providing data from orbit, work continued on the design and manufacture of new and follow-on spacecraft.

PLANETARY

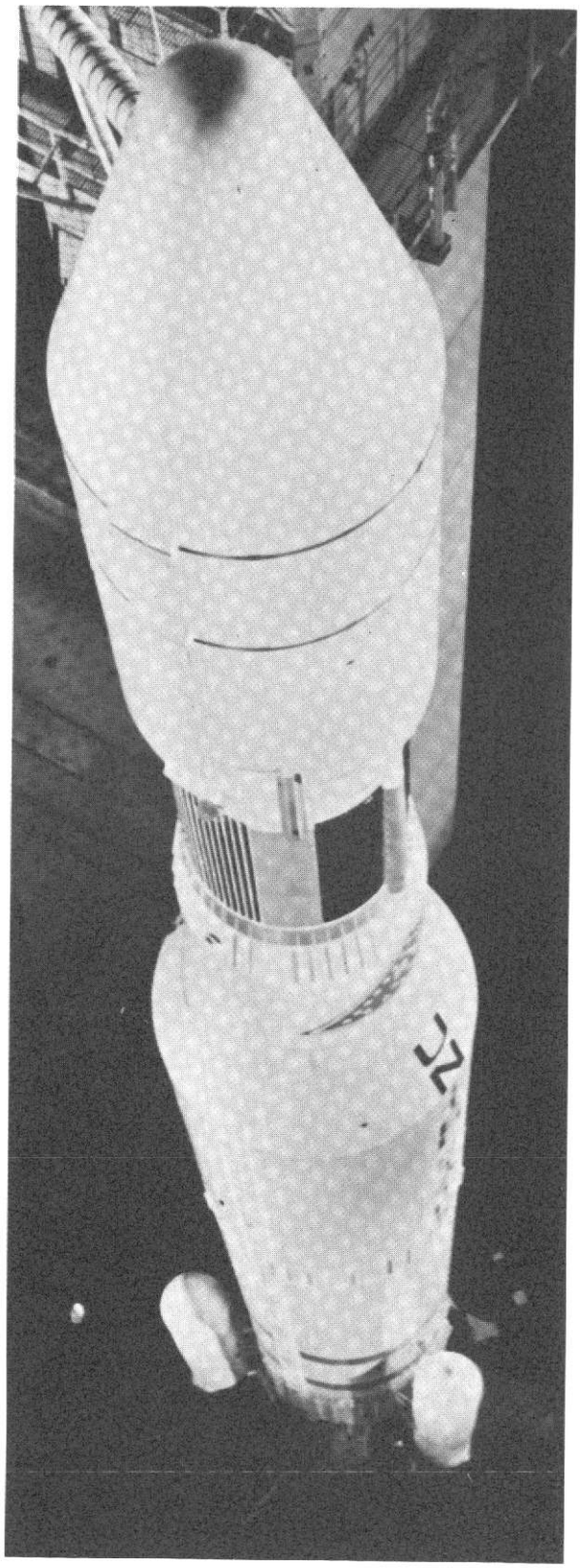
Helios: A cooperative program between NASA and West Germany to launch into orbit around the sun a series of two automated satellites for investigation of the properties of and processes in interplanetary space in the direction of and close to the sun (about 0.3 AU). The first helios is scheduled for launch late in 1974 and will have a projected lifetime of 18 months. The second Helios will be launched in 1975.

PHYSICS AND ASTRONOMY

Small Astronomy Satellite (SAS-C): The third of this highly successful series is scheduled for launch in 1975. It will be placed in a circular, equatorial orbit to measure discrete extragalactic sources, to monitor the intensity and spectra of galactic X-ray sources, and to minitor the X-ray intensity of Sco X-1.

Orbiting Solar Observatory (OSO-I): Provides a means for continuing efforts to observe the active physical processes on the sun by which the sun influences the earth and its space environment, and to advance our understanding of the sun's constitution and behavior. OSO-I is scheduled for launch in 1975.

United Kingdom 5 (UK 5): Part of the cooperative program between NASA and the United Kingdom. In 1974, UK 5 will be placed in a circular, equatorial orbit to investigate galactic and extra galactic X-ray sources.



ITOS-F on Goddard's Delta Vehicle – Ready for Launch

Astronomical Netherlands Satellite (ANS): A cooperative program between NASA and the Netherlands. In a slightly elliptical polar orbit, the ANS will obtain distribution and other data from celestial X-ray and ultraviolet sources. It is scheduled for launch in 1974.

Atmospheric Explorers – D&E (AE-D&E): Follow-ons to previous AE satellites, these satellites, scheduled for launch in 1975, will continue the investigations of the photochemical processes accompanying the absorption of solar ultraviolet radiation in the earth's atmosphere (see AE-C description).

Italian San Marco (C-2): A continuation of the cooperative program between NASA and Italy. In early 1974, a San Marco spacecraft will be launched from an equatorial platform to perform local density measurements by both the Italian drag balance technique and the U.S. mass spectrometry technique.

German Aeronomy Satellite (AEROS-B): In mid 1974, a follow-on German aeronomy satellite will be launched into an elliptical orbit with a very low perigee (230 Km). An onboard propulsion system will be used to raise apogee and prolong density and composition measurements.

Spanish Satellite (INTASAT): The Spanish satellite containing an ionospheric beacon for the synoptic study of the ionosphere will be launched into a sun-synchronous orbit in 1974.

COMMUNICATIONS

Applications Technology Satellite-F (ATS-F): A continuation of the highly productive applications technology development program, the ATS-F satellite, scheduled for launch in 1974, will provide a base for the most extensive communications testing ever attempted including educational television, tracking and data relay experiments. (see pages 35, 36, and 37 for additional information.)

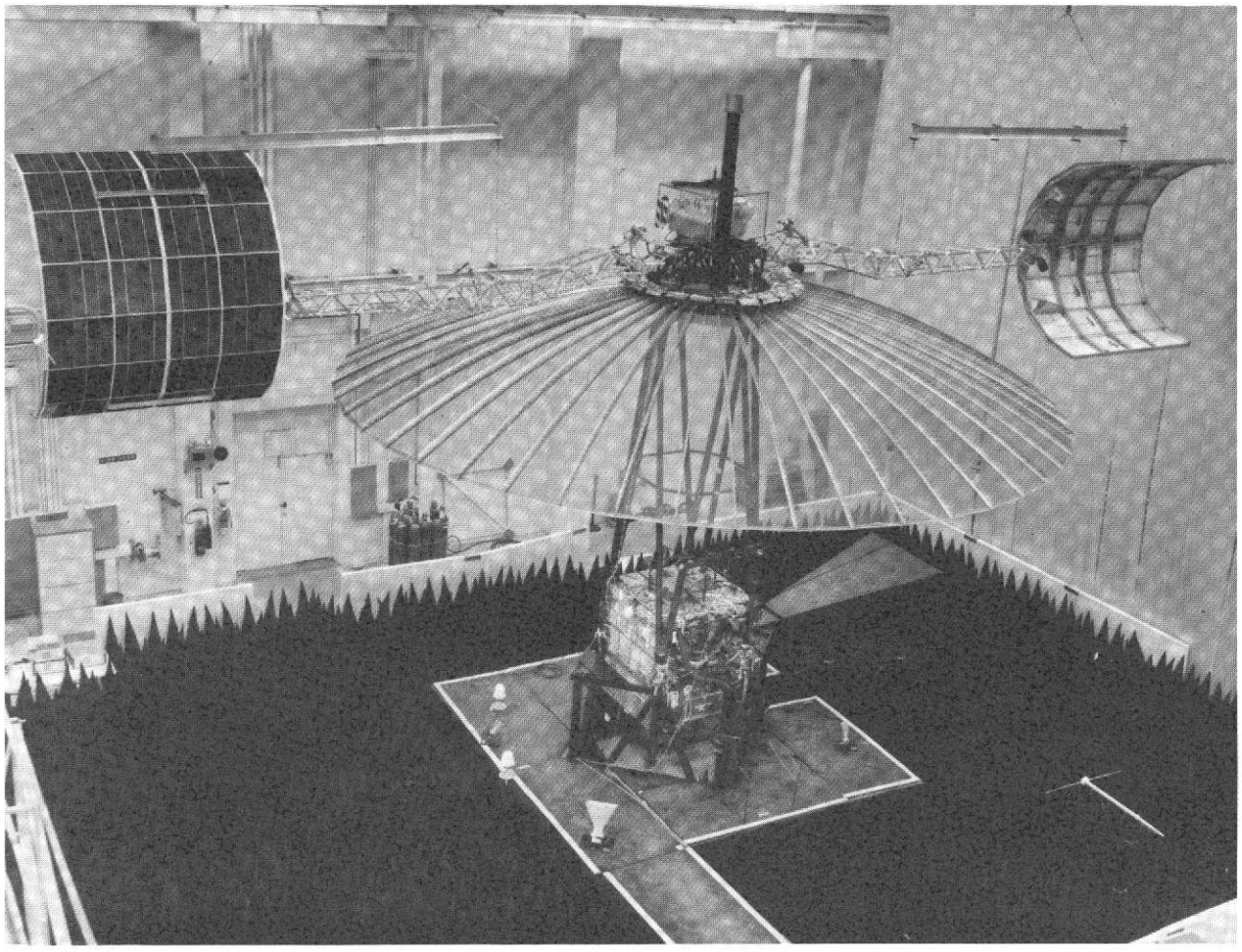
Cooperative Applications Satellite-C (CAS-C): Part of the cooperative program between NASA and Canada for an experimental communications technology satellite to advance the state of the art in spacecraft and ground technologies. The CAS-C satellite is scheduled for launch in 1975.

Geodetic Earth Observation Satellite-C (GEOS-C): An extension of NASA's geodetic program to demonstrate and calibrate satellite altimeter to absolute accuracy of five meters and relative accuracy of one to two meters. This spacecraft, in conjunction with ATS-F will also be used to establish precision capability of satellite-to-satellite tracking. Altimeter data will be used for preliminary evaluation of altimeter-improved oceanic geoid.

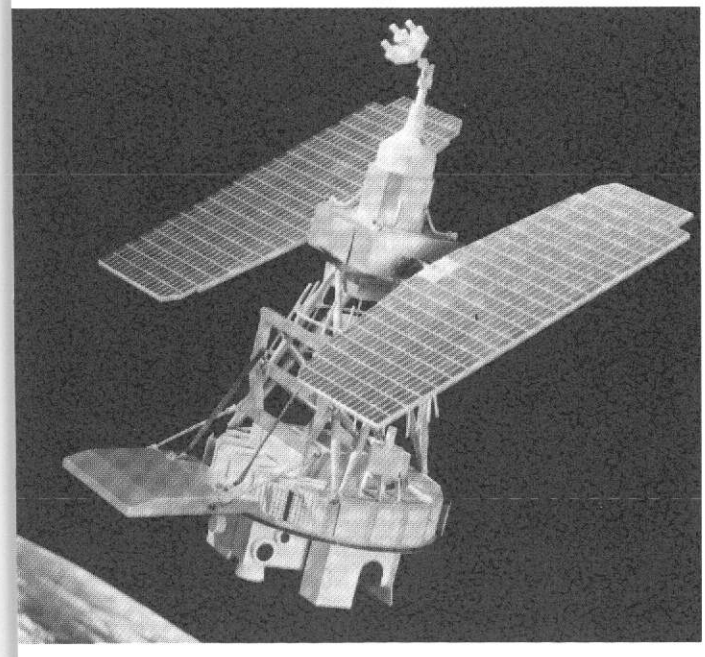
EARTH OBSERVATIONS

Improved TIROS Operational Satellite-G (ITOS-G): The 27th satellite in the TIROS series program and the seventh ITOS version. The ITOS satellites, developed, launched, and operated initially by Goddard, are operational weather satellites of the National Oceanic Atmospheric Administration (NOAA) providing global daytime and nighttime weather information to the meteorological community (see ITOS-F description).

Synchronous Meteorological Satellites – A&B (SMS-A&B) and Geostationary Operational Environmental Satellite-A (GOES-A): A series of developmental satellites to be placed into geostationary (synchronous) orbits to provide meteorological and environmental information. The satellites will be flight tested in orbit and will then be turned over to the National Oceanic and Atmospheric Administration for operational use. Scheduled launches for SMS A&B are in 1974. GOES-A is scheduled for launch in 1975.



Applications Technology Satellite in Test



Earth Resources Technology Satellite-B (ERTS-B): Second in this series, ERTS-B is scheduled for launch in 1975. Goddard's role is to design, develop, and launch ERTS spacecraft into medium altitude orbits for the purpose of conducting a variety of experiments in the earth resources disciplines (see ERTS results).

NIMBUS-F: Research and development meteorological satellites leading to advanced operational weather satellites for global sounding of the earth orbit. NIMBUS-F is scheduled for launch in 1974.

SOUNDING ROCKET PROGRAM

During the year the Center continued its support of Sounding Rocket experiments. There were 55 flights in the following breakdown and disciplines: 16 in the Galactic Astronomy, 16 in Solar Physics, 7 in Aeronomy, 11 in Energetic Particles and Ionospheric Physics and 5 in Vehicle Development. These included 17 flights which had STRAP attitude control systems for high accuracy pointing requirements. Some significant highlights of these launches are:

Seven pointed payloads were successfully launched from Australia within a two week period with all mission objectives met.

A Black Brant VC was flown at a 186 mile altitude at WSMR, with a University of Colorado payload setting an altitude record at WSMR for a single stage NASA rocket.

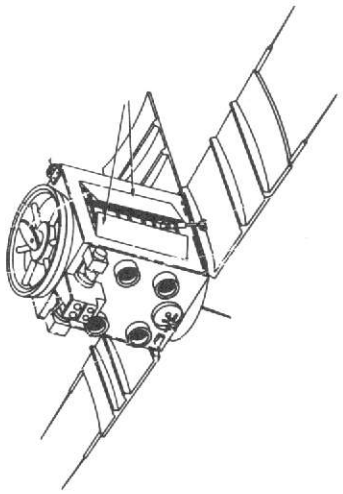
The first NASA Nike Tomahawk with a recovery system was successfully launched at WSMR.

The Skylab CALROC series was successfully completed. (See Solar Physics Rocket Program.) This series included some of the most sophisticated science rocket systems, instrumentation systems, and ground systems developed to date.

A science payload was successfully pointed to measure X-rays from the sun and SCO-XI which was separated by 160°.

Another payload was pointed to within 10 arc sec. accuracy at 3 discrete X-ray sources.

International program participation was expanded to include Denmark and the Netherlands.

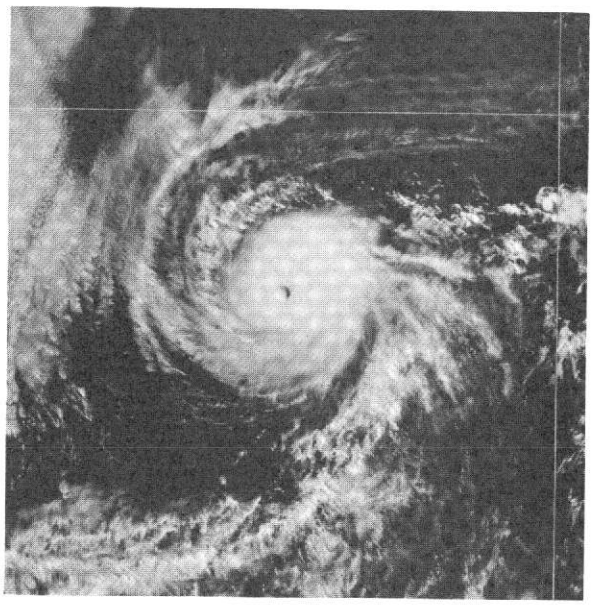


IMPROVED TIROS OPERATIONAL SATELLITES

In 1973 two ITOS satellites were launched: ITOS-E on July 16, and ITOS-F (1973 – 086A) on November 6. ITOS-E failed to achieve orbit because of a second stage malfunction of the launch vehicle. ITOS-F was successfully placed in a sun-synchronous orbit. NASA's mission for ITOS-F included responsibility to develop and manufacture the spacecraft, to launch it into a sun-synchronous orbit, and to conduct an in-orbit evaluation and checkout of the spacecraft. All of these requirements have been accomplished, and operational control has been transferred to the National Oceanic Atmospheric Administration (NOAA).

ITOS-F was the 26th in the series of TIROS spacecraft. The TIROS project was first initiated by the Advanced Research Project Agency of the Department of Defense and project responsibility was transferred to NASA when it was founded in 1959. The first nine TIROS satellites were considered research and development efforts for the purpose of developing spacecraft, sensors, and systems for obtaining meteorological information during both daytime and nighttime periods.

In order to provide systematic and regular global and local weather analysis for forecasting, an operational satellite system was required. In 1962 the Department of Commerce and NASA agreed to jointly fund a program to develop such a system. The TIROS spacecraft was chosen as the basis for the system, and three experimental satellites were launched between July 1965 and February 1966.



Following the successful performance of the three experimental spacecraft, NASA built and launched the first seven TIROS Operational Satellites (TOS) which were fully funded by the Department of Commerce. The TOS system employed two operational spacecraft to obtain meteorological data daily for the entire globe.

The economical advisability of a single spacecraft system and the numerous improvements in the development of TOS led to the involvement of an Improved TIROS Operational Satellite (ITOS). The first of this series was TIROS "M" (1970 – 008A) which was a NASA-funded R&D spacecraft. The Department of Commerce funded the sensors and ground equipment. TIROS "M," launched January 23, 1970, was the 20th satellite in the TIROS series. As the prototype spacecraft for the second generation operational meteorological spacecraft, it met its mission as an economical and stable platform suitable for providing global daytime and nighttime observations of the earth's cloudcover on a regular daily basis.

Following TIROS "M," the first four fully operational ITOS satellites were launched and have provided:

Daytime and nightime global cloudcover data on a regular daily basis.

Global solar proton density data on a regular daily basis.

Global heat balance data on a regular daily basis

Very high resolution visible and infrared cloudcover data to selected areas on a direct readout basis and stored cloudcover data of selected areas.

Global sounding of the atmosphere on a regular daily basis.

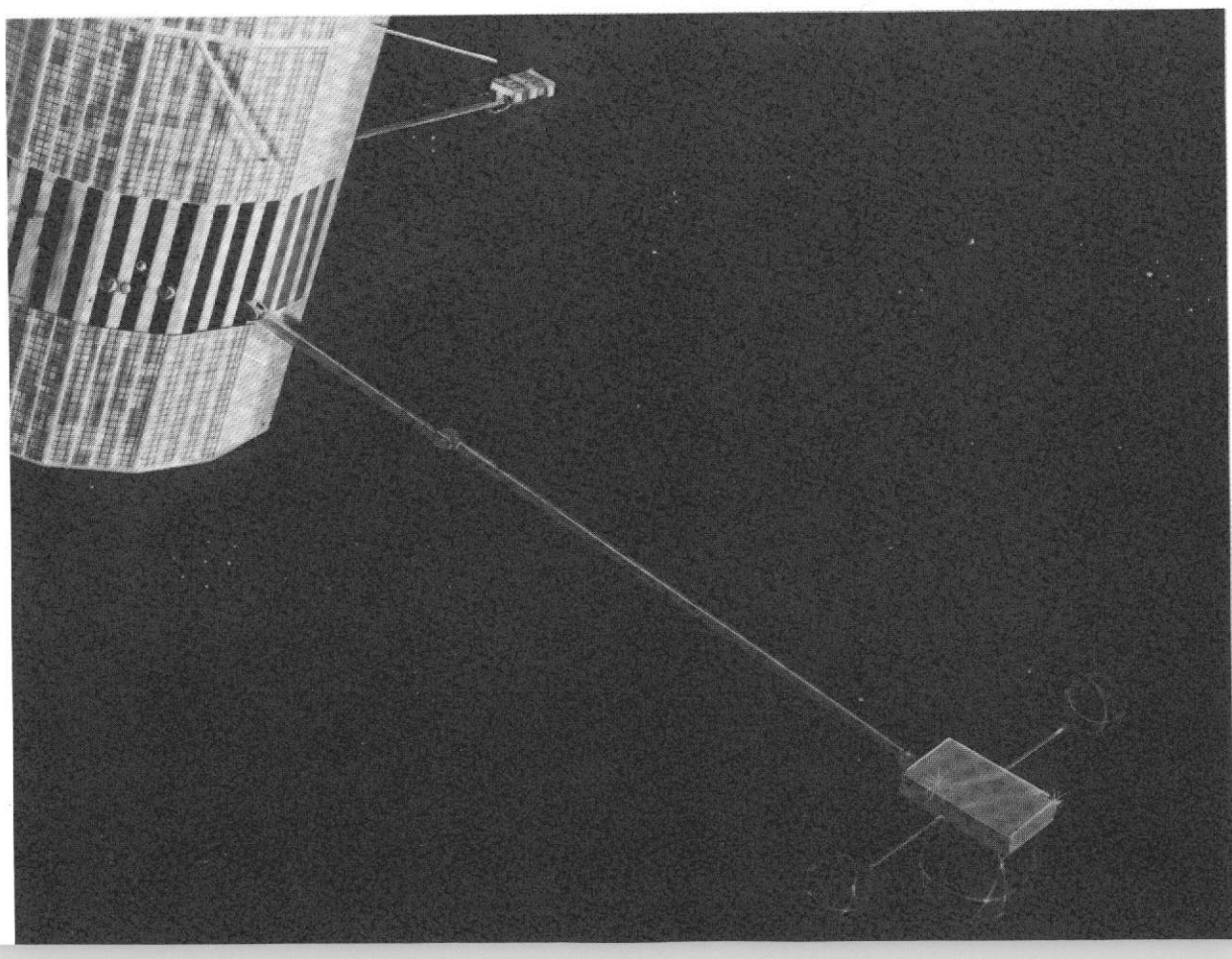
ITOS-F is currently providing the above information to the National Environmental Satellite Service at Suitland, Maryland, for analysis and dissemination to the meteorological community. Data are also sent to the Global Weather Center, Offutt Air Force Base, Omaha, Nebraska.

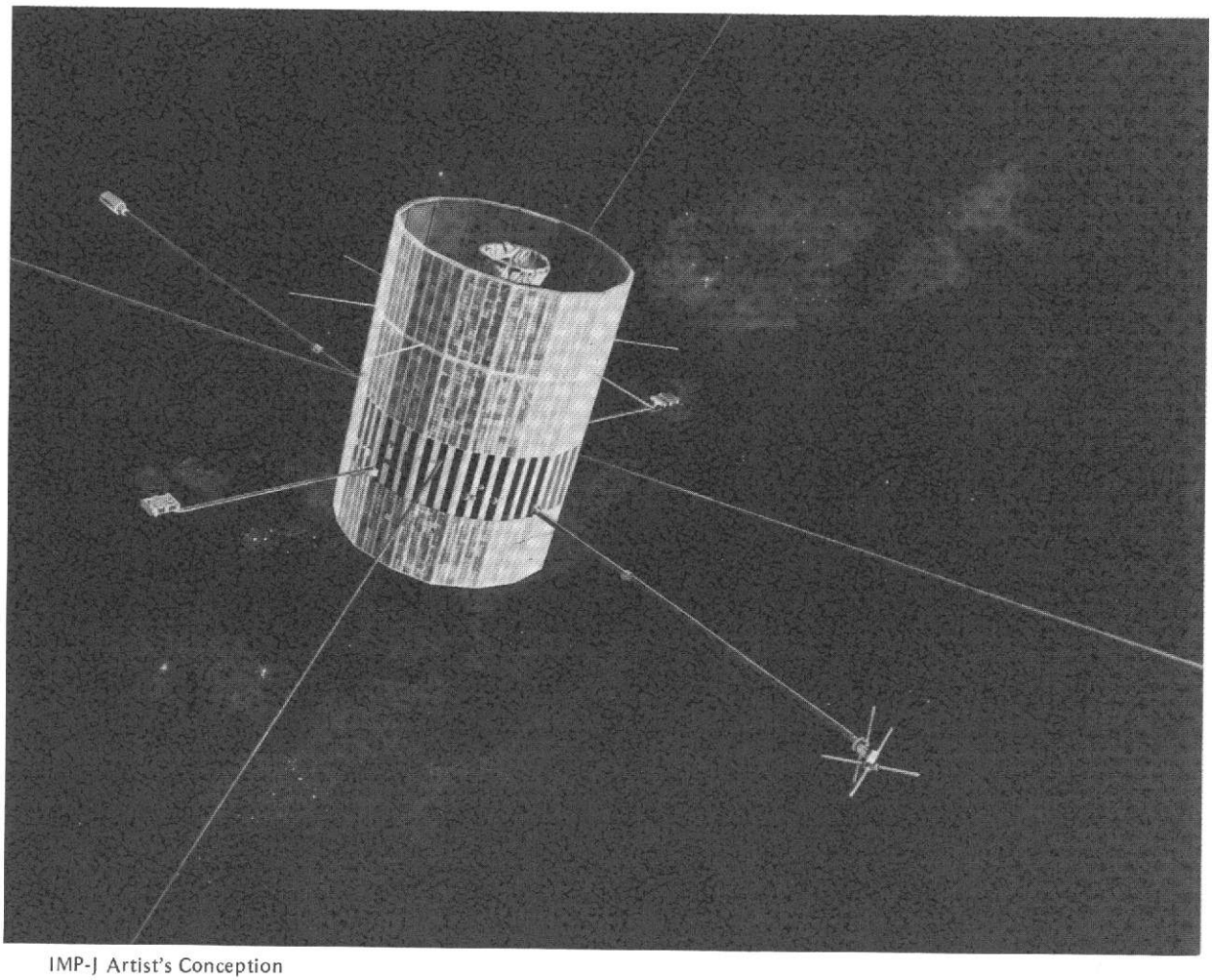
INTERPLANETARY MONITORING PLATFORM (IMP-J)

IMP-J, (1973 – 078A) the tenth in the series, was successfully placed into a high, elliptical orbit having an apogee of about 289,000 km and a perigee of about 141,000 km. Launched October 25, 1973, IMP-J is designed to perform detailed and near continuous studies of the interplanetary environment for orbital periods comparable to several rotations of active solar regions and to study particle and field interactions in the distant magnetotail, including cross sectional mapping of the tail and neutral sheet.

A series of IMPs – essentially a continuation of the NASA series of energetic particle spacecraft – have been launched since 1963 to study and monitor the plasmas, magnetic fields, and energetic particle population of interplanetary space. Previous IMP missions have had either a highly elliptical earth orbit or a moon orbit. IMP-J is in a slightly elliptical earth orbit, nominally halfway to the moon and 180° out of phase with its sister spacecraft IMP-M. This allows separate and correlative measurements to be concentrated on the earth's tail and its relationship to the solar wind. Its orbit is designed to permit continuous monitoring of the interplanetary medium and the geomagnetic tail-plasma sheet throughout an entire year.

The IMP-H and J missions continue the significant forward progress in the evolution of earth-orbiting IMPs. In addition to a sizable increase in experiment weight, information rate, and available power, there was also a change in the basic philosophy behind many of the experiments. Earlier IMP spacecraft were primarily designed to carry out exploration of the near interplanetary region and the outer portions of the earth's magnetosphere and to investigate the interactions of the earth-sun system. Later IMPs were designed for continuing these studies and mapping of the magnetic fields, solar plasma, energetic particles and micrometeorite fluxes in the vicinity of and in orbit around the moon. The IMP program has now covered the major part





IMP-J Artist's Conception

of an 11-year solar cycle, from the declining phase of the last cycle, through solar minimum, and through solar maximum. IMP-J continues to study the earth-sun system in near interplanetary space, as well as studying dc electric fields along with the physical mechanisms involved and the dominant processes of the earth-sun environment in order to provide a detailed understanding of the regions broadly surveyed by the eight previous IMP spacecraft.

The IMP series of spacecraft have proved to be highly successful scientifically and have provided the first accurate measurements of the interplanetary magnetic field, the magnetosphere boundary, and the collisionless magneto-hydrodynamic shock wave associated with the interaction of solar wind with the geomagnetic field. Measurements from all solar elliptical longitudes have permitted a mapping of the earth's magnetic field within the magnetosphere. The detection of an extended geomagnetic tail plasma sheet represents the most important result with respect to the earth's outer magnetic field.

Experiments carried on the first three IMP spacecraft found that a directed flux of plasma ions in the interplanetary region is always observed far from the earth where the plasma motion is unaffected by the geomagnetic field. The existence of ion flow, termed the solar wind, had been inferred by the motion of comet tails and confirmed by observations on a U.S.S.R. satellite, as well as on Explorer 10 and Mariner 2. The bulk velocity of the solar wind was found, generally from solar direction, in the range from 300 to 550 km/sec. On the sunlight side of the

magnetosphere at least two transitions in the properties of the plasma are observed for each orbit on both the inbound and outbound passes. One transition can be identified with the magnetopause and the other with a shock front created by the supersonic plasma stream. At the subsolar point typical geocentric distances to these regions are 10 and 14 earth radii, respectively. At the down side of the magnetosphere, these distances increase to 14 and 23 earth radii.

Detailed mapping of the earth's magnetic field on the nighttime side has revealed a significant magnetic tail that does not co-rotate with the earth. The magnetic lines of force on the earth's nighttime side having L values of less than 8 appear to co-rotate with the earth, while a large, sheet-like, magnetically neutral surface develops within the magnetic tail as a result of the proximity of lines of force oppositely directed which appear directly connected to the polar cap regions. Significant time variations of the magnetic field in the earth's tail are in opposition with the solar phase of the geomagnetic sudden-commencement storms. Thus, the tail appears to play a dominant role in various terrestrial phenomena. This neutral sheet is populated with energetic electrons that may be the source of radiation leading to auroral displays and the Van Allen radiation belt.

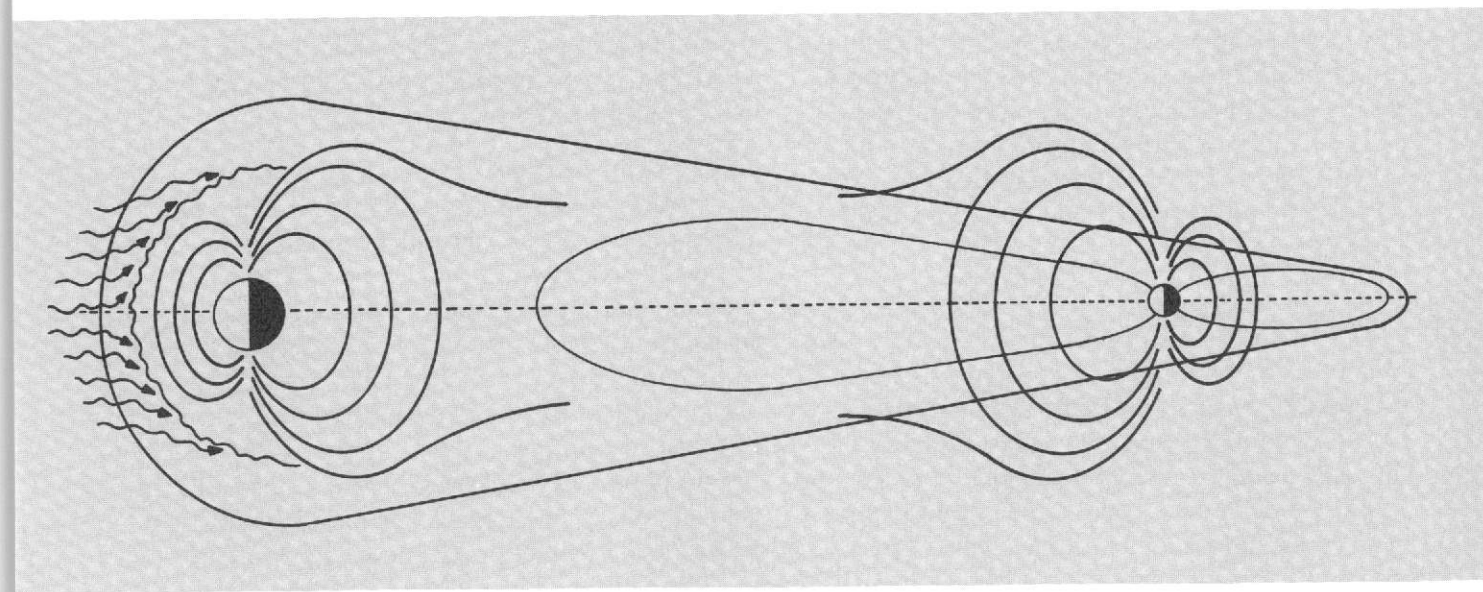
To obtain the measurements necessary to continue these investigations, IMP-J carries 12 scientific experiments as follows:

Magnetic Fields: The vector magnetic field is being measured in three dynamic ranges — ± 12, ± 36, and ± 108 gammas. These data permit the study of the interplanetary magnetic field, the earth's magnetic tail, and the interaction of the solar wind with the geomagnetic field.

DC Electric Fields: The electrostatic dc electric field is measured in the solar wind, in the transition region, and in the geomagnetic tail. These data are being correlated with plasma and magnetic field measurements also made by IMP-J.

AC Electric and Magnetic Fields: The spatial and temporal characteristics of both electric and magnetic ac vector fields and their polar relationships along the IMP-J orbit are being measured. These data will enhance understanding of plasma dynamics, the earth's shock front, and acceleration of particles.

Cosmic Rays: Two separate cosmic ray experiments are carried on IMP-J. One experiment is part of a systematic program to study solar and galactic electrons and nuclei throughout the solar cycle. It permits the



study of solar modulation, quiet-time and flare-associated anisotropies, solar and magnetospheric acceleration processes, and solar composition.

The second cosmic ray experiment is designed to study solar flare particle acceleration and particle containment in the vicinity of the sun. It measures energy spectra, nuclear composition, and electrons over a wide range of energies and a wide dynamic range of fluxes.

Energetic Particles: This experiment provides data for the study of the propagation characteristics of solar cosmic rays through the interplanetary medium, electron and proton patches throughout the geomagnetic tail and near and through the flanks of the magnetopause, and the entry of solar cosmic rays into the geomagnetic field by utilizing comparisons with similar data from the TIROS series of satellites.

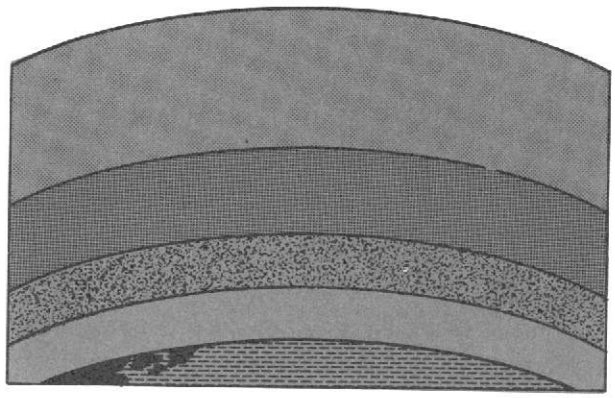
Charged Particles: These data are being used to study angular distributions, energy spectra, propagation characteristics, and absolute intensities of particles emitted from the sun, as well as those streaming along the magnetospheric tail away from the earth.

Electron Isotopes: By measuring the differential energy spectra of electrons and hydrogen and helium isotopes, this experiment permits study of the local acceleration of particles, solar particle acceleration and storage in the interplanetary medium, and the interstellar propagation and solar modulation of particles in the interplanetary medium.

Ion and Electron: This experiment determines sign and magnitude of change; measures the energy of cosmic ray particles; and uniquely identifies positrons, electrons, protons, helium nuclei, and CNO nuclei. These data will help scientists to determine the composition and energy spectra of low energy particles observed during solar flares and "27 day" events.

Low Energy Particles: This experiment measures low energy electrons and protons to study the differential energy spectra over the geocentric radial distance of 40 earth radii to increase our understanding of geomagnetic storms, aurora, tail and neutral shield, and other magnetospheric phenomena.

Plasma: Two plasma experiments are carried by IMP-J. One instrument is used to make a comprehensive study of electrons and positive ions in the regions of space traversed by the satellite and to coordinate them with magnetometer and other scientific data. The other plasma experiment measures the energy and angular distribution of protons and electrons in the interplanetary region, the transition region, and in the tail of the magnetosphere.



ATMOSPHERIC EXPLORER-C (AE-C)

The primary objective of the Atmospheric Explorer program is to conduct carefully coordinated experiments to solve a number of well defined aeronomic investigations associated with the chemical and energy balance of the thermosphere, that region of the upper atmosphere between 150 and 500 kilometers. AE experiments are oriented primarily to the largely unexplored low-altitude region between 150 and 300 km in order to explain the chemical, energy absorption, conversion, and transport processes which control the structure of the upper atmosphere. The AE-C objective is to investigate the photochemical processes accompanying the absorption of solar ultraviolet radiation in the earth's atmosphere by making closely coordinated measurements of the reacting constituents from a spacecraft having varying or adjustable perigee and apogee altitudes.

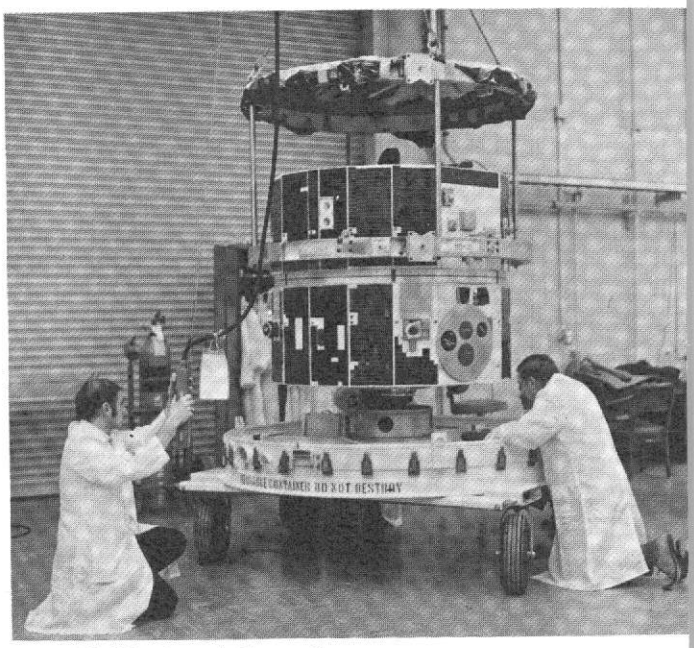
AE-C was launched December 16, 1973 and is the third in this series. AE-A (1963 – 009A) and AE-B (1966 – 044A) were launched in 1963 and 1966, respectively. The AE-A&B missions, along with sounding rocket experiments, identified the need to conduct satellite measurements at altitudes significantly lower than those normally maintained by satellites. In particular, it was evident that the behavior of the upper thermosphere is strongly governed by the lower thermosphere. Experimental study of the lower thermosphere has thus become one of the primary goals of the aeronomy program.

AE-C is the first of three satellites (the other two are designated D&E) to be placed in highly eccentric orbits with perigee near 150 km and apogee near 4000 km. Periodically the orbit perigee of these spacecraft will be lowered for brief periods to the lowest altitude consistent with spacecraft and instrument safety. After a period of time, apogee will be allowed to fall, and a sequence of circular orbits will be established at each of several pre-selected altitudes in the range of 250 to 700 km.

The AE-C mission is specifically directed toward the study of the chemical and energetic processes controlling the structure of the thermosphere. Prime emphasis is placed on the lower thermosphere which has not been explored by direct measurement satellites. There are 14 experiments and sensors on the AE-C spacecraft, as follows:

Ultraviolet Nitric-Oxide Experiment: A two-channel, fixed-grating Ebert spectrometer which, as the satellite spins, repeatedly looks downward through the atmosphere onto the earth's limb obtaining altitude profiles of emitted airglow intensity.

Cylindrical Electrostatic Probe: Obtains measurements of electron temperature and concentration required for studies of the thermal and particle balance of the thermosphere.



AE-C Pre-Launch Preparations

Positive Ion Mass Spectrometer: Measures, through the 120- to 4000-km orbit, the concentration of thermal positive ions.

Atmospheric Density Accelerometer: By measuring satellite deceleration due to dynamic drag, this experiment provides data to determine the neutral density of the atmosphere in the altitude range between 120- and 400-km.

Photoelectron Spectrometer: Provides information on the intensity, angular distribution, energy spectrum, and net flows along field lines of the low energy electron flux.

Planar Ion Trap: A planar retarding-potential analyzer which supplies ion-temperature and ion-concentration data. In addition, the instrument determines ion-drift velocities and energy spectra of both the thermal and suprathermal electrons.

Visual Airglow Experiment: A filter photometer which monitors airglow and auroral-emission which lie in the spectral region between 3000 and 7500 Angstroms.

Solar EUV Filter Photometer: Records solar irradiance in seven wavelength bands from 40 to 1250 Å to measure time dependence.

Solar EUV Spectrophotometer: Measures solar radiation at wavelengths ranging from 140 to 1850 Å.

Magnetic Ion Mass Spectrometer: Measures the abundances of the ambient positive ions in the ionosphere.

Low Energy Electron Spectrometer: Provides differential measurements of the energy influx and angular distributions of electrons and protons.

Open-Source Neutral Mass Spectrometer: Measures the in-situ concentrations and distributions of the neutral gas constituents in the thermosphere to help determine the instantaneous and global distribution of neutral hydrogen, helium, atomic and molecular oxygen, nitrogen, argon, and total mass density above an altitude of 120 km.

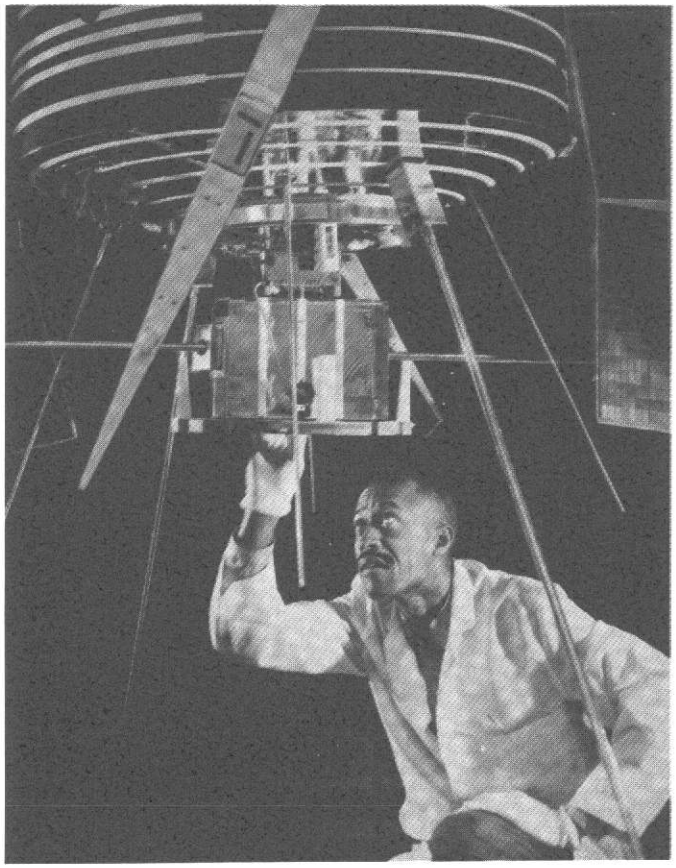
Closed-Source Neutral Mass Spectrometer: Obtains in-situ measurements of neutral thermosphere composition. Correlation of the measurements with simultaneous measurements by the Open-Source Spectrometer, Solar EUV Spectrophotometer, and Density Accelerometer experiments may provide new insight into in-situ measurement techniques.

Neutral Atmosphere Temperature Experiment: Provides with five percent accuracy, a determination of the temperature of the neutral gas at the location of the satellite based on measurement of the velocity distribution of the molecular nitrogen.

In order to optimize the scientific return and achieve maximum utilization of the variable orbit capabilities of the AE spacecraft, an on-line central processing/analysis system was provided. Short turn-around times (one to several days) on analysis of selected aeronomy problems permit adaptive mission planning. For example, it may be desirable to study a particular latitude in the northern hemisphere at a perigee of 150 km during a highly disturbed condition for three consecutive days after noting the condition existing during a one-day low perigee excursion. This type of adaptive planning is made possible by means of the fast turn-around analytic capability of the central processor.

RADIO ASTRONOMY EXPLORER-B

Radio Astronomy Explorer-B (RAE-B) was successfully launched June 10, 1973. This was the second in the Radio Astronomy Explorer series following almost five years after the launch of the highly successful RAE-A (1968 – 055A).



Engineering Technician Examines RAE-B Libration Damper Mechanism

The Science of Radio Astronomy: The recent growth of astronomy has been greatly stimulated by the ability to mount astronomical instruments on observing platforms high above the earth's atmosphere. Prior to this capability, about 30 years ago, the known spectrum of radiation reaching the earth's surface was only slightly broader in wave-

length than the visible spectrum 4000 - 7000 Å. The short wave radiation below 3000 Å emitted by the sun and stars, as well as aprt of the infrared above 10,000 Å are blocked out by the earth's atmosphere. There was little reason to suspect that any significant number of astronomical bodies were radio emitters, and Jansky's early observations of apparent radio waves from the Milky Way aroused little interest among astronomers. With observations restricted to a small fraction of the electromagnetic spectrum, astronomers could only deduce the physical nature of objects emitting primarily thermal radiation at a temperature of a few thousand degrees.

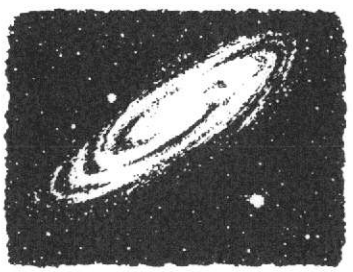
Other regions of the spectrum began to be exposed until the entire electromagnetic spectrum was opened to investigation. It is now possible to devise and carry out decisive experiments to test almost any hypothesis in astrophysics. This possibility exists because many well defined scientific problems can be solved by multiwavelength experimental approaches, and many unexpected discoveries are made when a new region of the spectrum is explored or when a new instrument of advanced capability is put into operation.

Radio astronomy has already revealed many exciting and unexpected phenomena. The study of the intense radio emission from interstellar space, supernovae and extragalactic sources has contributed greatly to the development of high energy astrophysics. Information about cosmic rays, magnetic fields, and the evolutionary state of the source has been deduced from these observations. The recent discovery of entirely new classes of celestial objects such as pulsars and quasars, which were not expected on the basis of optical observations, suggests the presence of highly energetic processes on a scale beyond thermonuclear levels. Galaxies have been discovered that have such an enormous radio output that detection at distances far greater than the limits of optical techniques offer the promise of probing the universe to enormous red shifts. Our own galaxy is pervaded by high energy particles (the cosmic rays), and radio observations of the galactic background are directly related to the electron component of this relativistic gas. Through the study of astrophysical plasmas, the production of energetic particles, the existence of collective motions, the presence of magnetic fields and the existence of coherent or MASER Processes, the possibility exists of solving the problem of plasma containment on earth creating the breakthrough that will provide inexpensive, unlimited electrical power with controlled thermonuclear fission.

Within the solar system, radio emission from traveling solar radio bursts and the sporadic emission from Jupiter involve dynamic processes from which general questions about particle acceleration and confinement may be answered.

While ground-based radio astronomy telescopes probe the radio spectrum from 10 to almost 10^5 MHz, only instruments riding above the terrestrial ionosphere can provide coverage at longer wavelengths between .01 to 10 MHz. In addition to the possibility of discovering entirely unexpected phenomena in this spectral region, there are some extremely important effects that can best be studied at longer wavelengths.

In general, these observations will lead to the establishment of an integrated model spectrum of the low frequency spectral characteristics of the galactic radio background and possibly discrete sources combined with ground-based observations of the high frequency behavior of the radio spectra.



NASA's Radio Astronomy Explorer Program: The primary objective of the Radio Astronomy Explorers is to measure the intensity of radio signals from celestial sources as a function of frequency, direction, and time in the frequency range below 10 MHz. Ground-based radio telescope observations are severely impaired below 20 MHz and are virtually impossible below 10 MHz because of ionospheric effects and terrestrial noise such as thunderstorms and man-made interference. Thus, the only possibility of extending observations into the frequency range below 10 MHz and down to the interplanetary cutoff at about .02 MHz is through the use of very high altitude sounding rockets and spacecraft that can make observations above the main portion of the ionosphere.

RAE-A the first successful radio astronomy satellite in an earth orbit of about 6000 km altitude has provided the first low resolution scan of our galaxy at low frequencies, the first complete cosmic noise background continuum spectrum measurements from .4 MHz to 6 MHz, as well as detailed dynamic spectra of solar radio bursts and detection of radio emissions from the earth's magnetosphere. Despite RAE-A's relatively high earth orbit, background noise from within the magnetosphere and terrestrial noise saturated the satellite's receivers up to 40 percent of the observing time and seriously affected overall results.

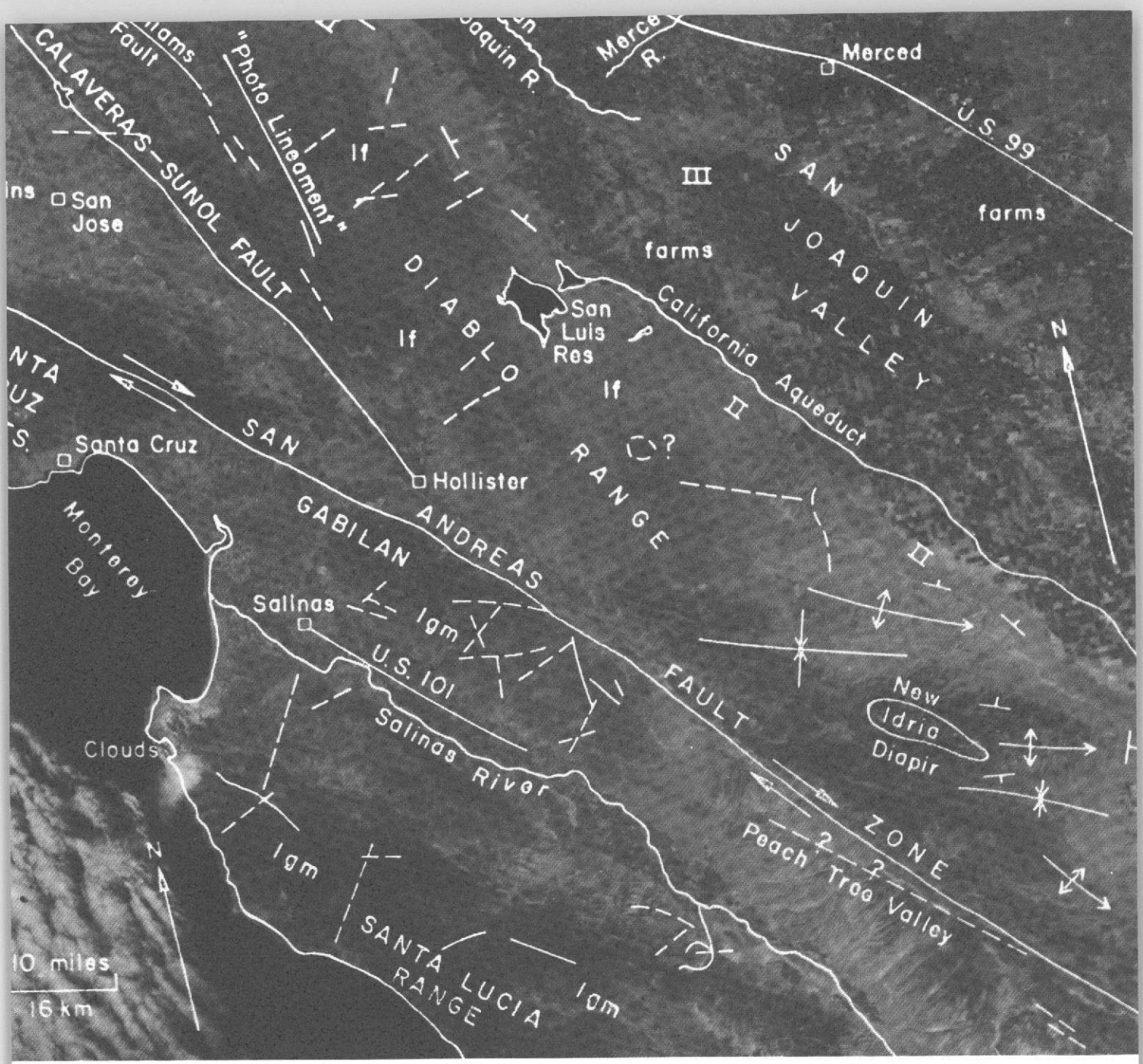
The RAE-B mission, with observations to be taken at lunar distances, was conceived to avoid these limitations and, therefore, provide an additional decade of frequency coverage beyond that of RAE-A down to the interplanetary cutoff (.02 MHz) from the ionospheric cutoff for the RAE-A altitude, at about .2 MHz. In addition, the lunar disk can be used for blocking magnetospheric and solar emissions and man-made transmission and possibly to provide a higher resolution and sensitivity through occultation.

Basically, RAE-B is an almost exact copy of RAE-A. Some updating of earlier subsystems has been made but the only major changes are those required by the lunar mission, which are the addition of a Velocity Control Propulsion System for translunar and lunar course correction and orbit eccentricity control and an Attitude Control Subsystem using cold gas sets, replacing the magnetic control subsystem on RAE-A to provide spin and precession control. Both of these subsystems have already been flight proven on other satellites.

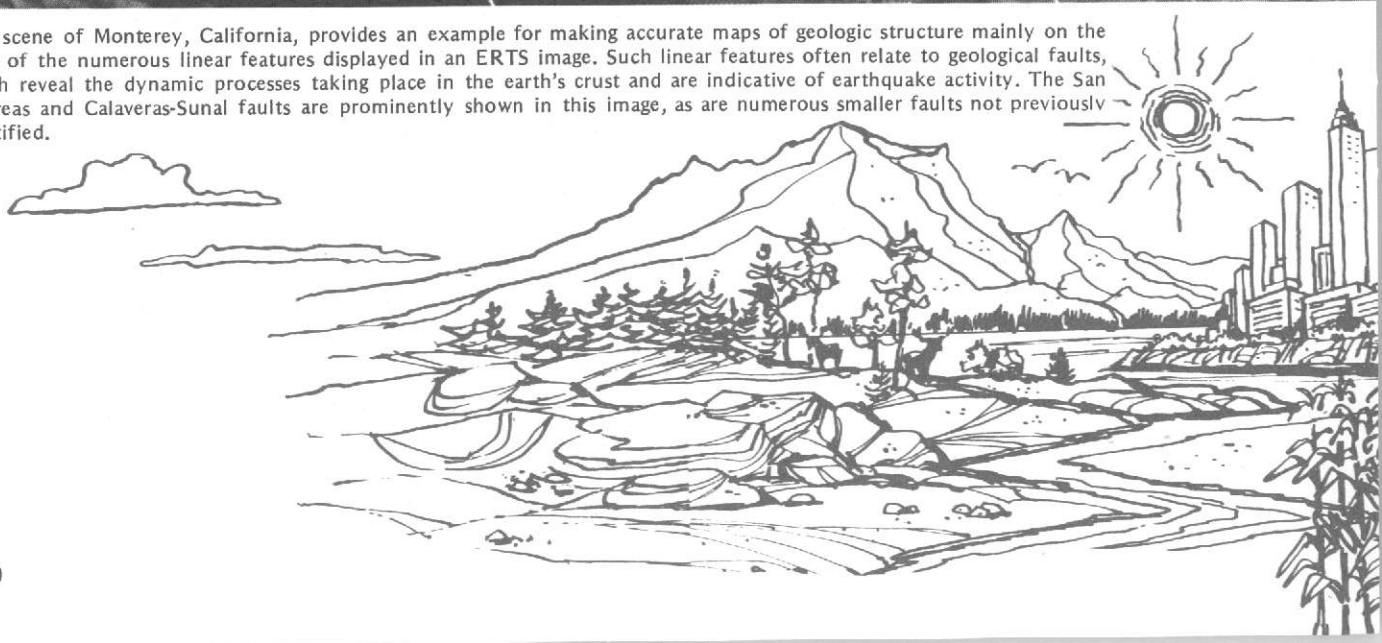
Three-axis stabilization in lunar orbit is assured by use of the unique experiment antennas forming two sets of Vs into an X shape with a tip-to-tip length of 1500 feet for each side of the X. This gravity gradient stabilization technique was demonstrated successfully with Explorer 38 which is believed to be the only long-term 3-axis fully gravity gradient stabilized spacecraft.

In its lunar orbit, RAE-B allows some unique science investigations not otherwise possible, such as:

- Extending of observations down to interplanetary cut-off frequency (~0.03 MHz).
- Obtaining positive identification and position of sporadic sources (e.g., sun, earth, Jupiter) and other sources by lunar disk occultation.
- Making observations which are free from all terrestrial interference when on the lunar side farther from the earth.
- Studying the radio-physics of the interplanetary medium and the earth's magnetosphere.
- Studying the terrestrial magnetospheric radiation from outside the magentosphere.
- Evaluating conditions for lunar radio measurements needed for long-range planning of orbiting- versus lunar-based observatories.



This scene of Monterey, California, provides an example for making accurate maps of geologic structure mainly on the basis of the numerous linear features displayed in an ERTS image. Such linear features often relate to geological faults, which reveal the dynamic processes taking place in the earth's crust and are indicative of earthquake activity. The San Andreas and Calaveras-Sunal faults are prominently shown in this image, as are numerous smaller faults not previously identified.



APPLICATIONS

The Applications Program of the Goddard Space Flight Center is directed toward developing and demonstrating practical uses of space technology. Programs are active in the disciplines of Weather and Climate, Earth Resources Surveys, Earth and Ocean Physics, and Communications and Navigation.

The Weather and Climate program is a continuation of the work begun with the first weather satellite TIROS-1 (1960 Beta 2), which was successfully launched on April 1, 1960. Although there is now a system of operational satellites which is managed by the NOAA, GSFC has continued NASA's research and development role through the series of Nimbus research satellites. The most recent Nimbus was launched on December 11, 1972. This spacecraft provided for the first time maps of the total liquid water content of the atmosphere and a global survey of sea ice by means of the electrically scanned microwave radiometer. During 1973, advancement of observing techniques was continued through preparations for launch in 1974 of the next Nimbus spacecraft.

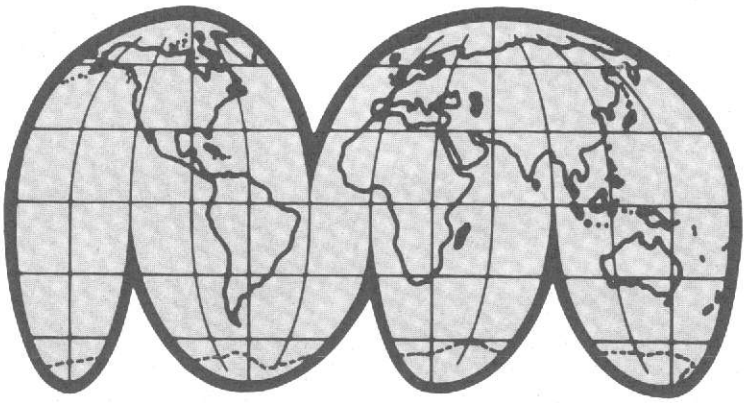
To assist in providing a means for better weather forecasting, the Goddard Institute for Space Studies has underway a major effort for the numerical modelling of the total atmosphere as a part of the Global Atmospheric Research Project (GARP).

The Earth Resources Survey program is intended to provide a means for collecting information which can contribute to the better management of the limited resources of the earth. Goddard's major participation in this program has been through the management of the Earth Resources Technology Satellite spacecraft program and the subsequent investigations in which the possible uses of the data obtained have been explored. Some of the significant results of ERTS were presented in symposia held in March and December 1973.

The Earth and Ocean Physics program has been an outgrowth of the work done to support satellite tracking and orbit determination. Through the necessity for obtaining accurate models of the earth's gravity field and the precise location of tracking stations, it has become possible to study the dynamics of the solid earth and the oceans including tectonic plate motion and both solid earth and ocean tides.

The Communications and Navigation program began at Goddard with the launch of the passive reflector Echo I (1960 Iota-1) in August 1960, the active low-altitude Relay I in December 1962, and the active synchronous Syncom II (1963 – 031A) in July 1963. The success of Syncom led to the operational Intelsat system operated commercially by COMSAT. Meanwhile, Goddard has pursued the research and development necessary for advancing communications technology. During 1973, the planning was continued for demonstrations of the usefulness of a high-gain pointable communications system to be flown on ATS-F to be launched in 1974. Experiments with education-via-television are to be conducted in remote regions in the Rocky Mountain states and with India.

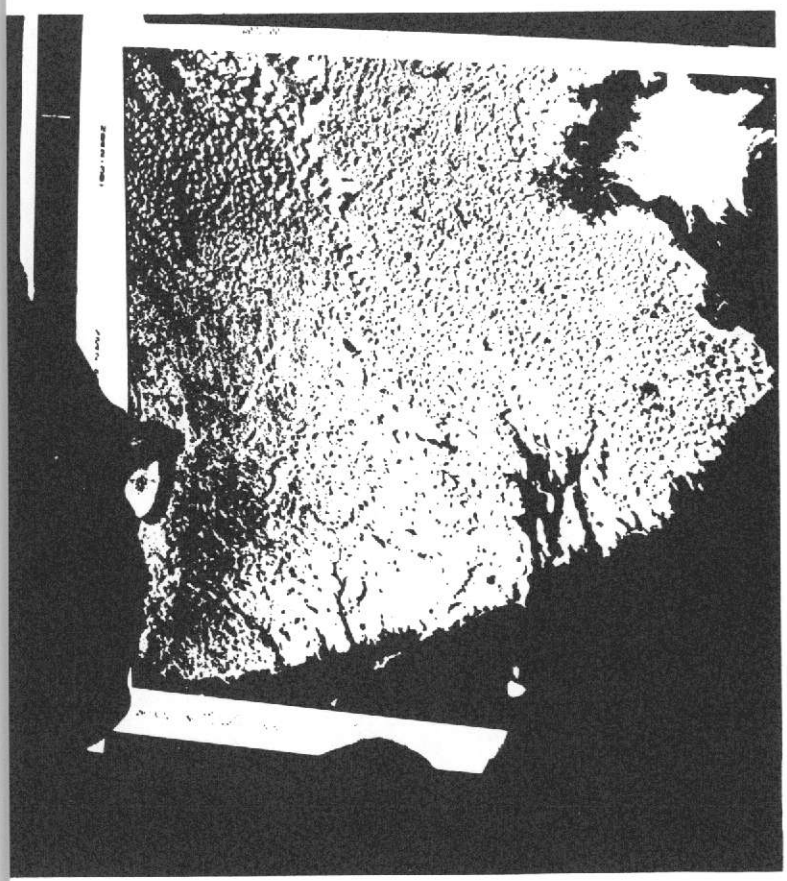
International Cooperation



EARTH RESOURCES TECHNOLOGY SATELLITE RESULTS

The first Earth Resources Technology Satellite (ERTS-1) was launched July 23, 1972. The purpose of the ERTS program is to verify the feasibility of remote sensing from a satellite as a technique for inventorying and monitoring the earth's resources to provide for better management of these resources. ERTS data are provided to about 300 investigators in 43 states, the District of Columbia, and 31 foreign nations.

In 1973 two major ERTS symposia were sponsored by GSFC, one in March and one in December. These symposia provided open forums where data users had the opportunity to present significant accomplishments from their investigations. A general summary of results discussed at these symposia is presented in the following paragraphs.



Environmental Impact: In recent years, citizens here and abroad have become increasingly concerned with the earth's environment. Some environmental impact data detected using ERTS data include:

- Evidence of chemical discharge from a New York paper mill into Lake Champlain prompted the State of Vermont to seek a cease-and-desist order through the courts. (This may be the first space evidence ever used in a legal proceeding.)

- Identification of areas of the Delaware Bay where currents would concentrate rather than disperse wastes make it possible to better plan near-shore dumping of municipal wastes.

- Observation of municipal waste dumping in predefined ocean areas off New York assure compliance with regulations protecting the coast from severe environmental contamination.

- Investigation of other environmental factors include coastal wetlands inventory and monitoring, strip mining contamination as well as reclamation monitoring, and some forms of air pollution detection.

Agriculture, Forestry, and Rangelands: Farmers, foresters, and range managers who deal with complex, dynamic, living "systems" have unique and exacting information requirements. As long as the crops are growing, the trees healthy, and rangeland normal, these people do not want to be deluged with information. But the moment problems start, they must know in order to begin remedial actions and minimize losses.

ERTS-1 has clearly demonstrated its capability as an "early warning" system by detecting vegetative stress conditions long before the symptoms are apparent to the human eye.

Left: Nations Capital Photographed from ERTS-1.
Right: NASA Administrator Examines ERTS Photograph.

The fact that ERTS observation provides such vast area coverage permits the monitoring of vegetation much more extensively and with greater rapidity than is possible from the ground or from aircraft. Once "normal" conditions have been charted, deviations from the normal can be quickly isolated and investigated in detail by air or ground survey.

Charting accuracy has been shown to approach 90 percent for major growing crops in many areas. This crop inventory data can be of great value to farmers. Using conventional methods such acreage estimates are tedious and expensive. ERTS data have reduced such estimating time by as much as 8:1.

Clearly there are many applications for the use of ERTS data in agriculture and forestry. These are being investigated and developed to establish techniques for improving watershed management, land use planning, and even wildlife management.

Marine Resource and Ocean Surveys: The earth's oceans cover nearly 75 percent of the globe. ERTS is providing information permitting investigation and analysis of sea ice; coastal processes, including suspended-sediment transport, near shore circulation patterns, beach dynamics, and river effluents; bottom topography; oceanic currents; and marine life detection and/or predictions.

Studies using ERTS and field data have shown that river runoff, ice melt, and oceanic waters can be readily distinguished, thus giving information concerning temperature, turbidity, and salinity. Areas of coastal oceanic turbidity are usually associated with either sediments dumped by rivers and streams or upwellings which bring suspended particles and nutrients to the surface. Locating areas of upwelling is important to the fishing industry since fish feed in waters of high nutrient content. ERTS images can identify such areas by the different spectral signature of heavy concentrations of suspended particles. Because of repeated coverage, determination can be made of geographic and physical changes in these upwelling areas.

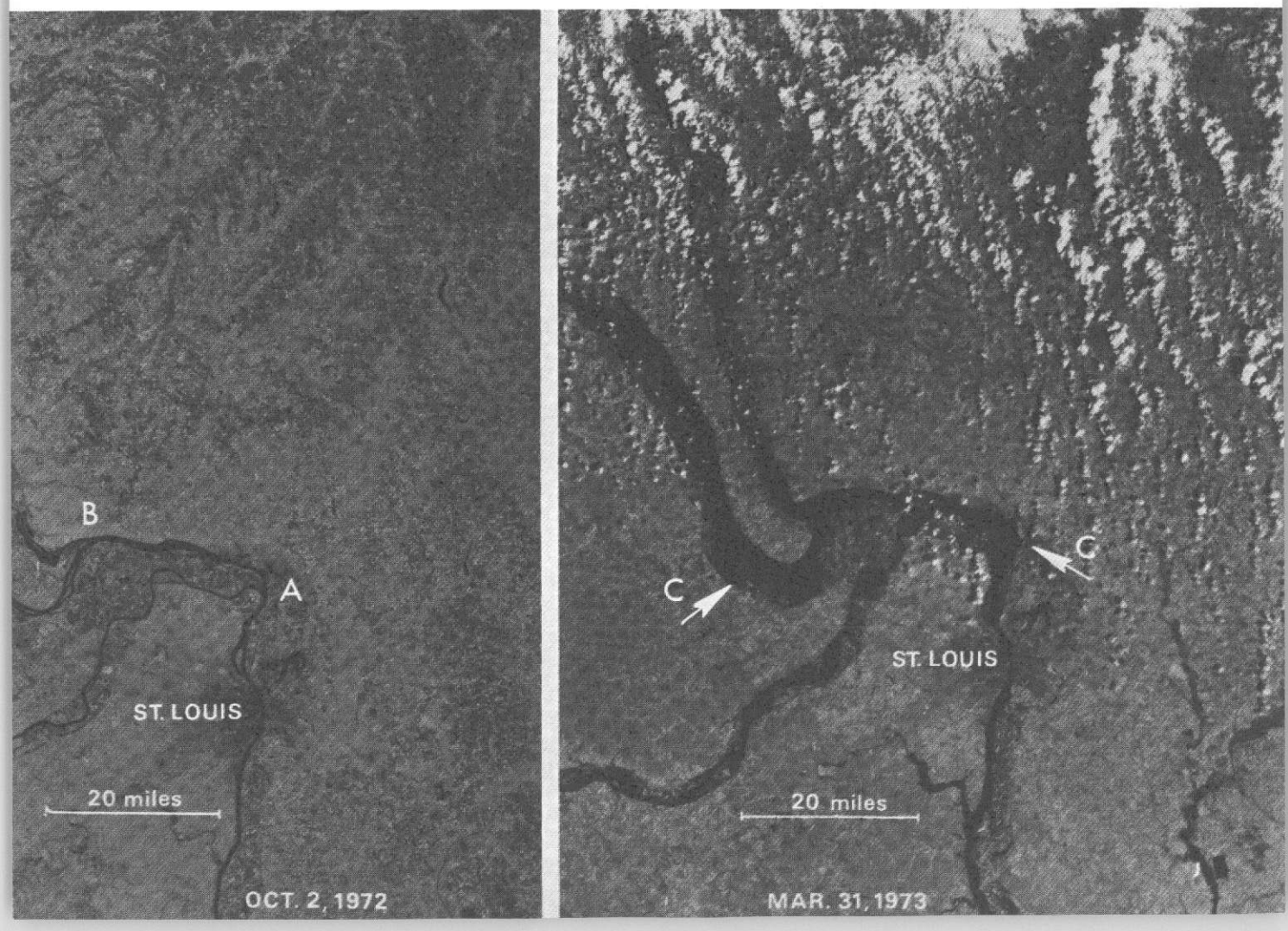
Geology: Man's ancient concern with the earth takes many forms, from "simply" wanting to depict (map) geological features and prospecting, to predicting – and even controlling – earthquakes and volcanic erruptions. ERTS and other satellite remote sensing has made possible major advances in all these areas.

In the regime of mapping, geologic maps produced from ERTS data were found to have the following advantages over maps produced by other techniques:

- In regions for which only poor quality or outdated maps have been produced, ERTS offers an excellent method for generating good general maps at small scale.
- Mapping from ERTS in rugged, inaccessible regions offers some obvious advantages.
- Existing maps can be checked against ERTS imagery to correct mislocated or omitted rock-unit contacts, geological structures (fold axes, for example), lava flows, etc.
- New or improved small-scale geologic maps (for example, those showing regional landforms, quaternary deposits in basins, sediment patterns, and distribution lineaments can be developed from ERTS images.

Another geologic application includes the study of landforms and dynamic surface processes. ERTS images hold a high potential for producing regional, small-scale landform maps which are practically nonexistent for most parts of the world. Mapping of regional

These ERTS-1 photographs show normal and flood conditions of the Mississippi River in the St. Louis area.



landforms has useful implications for engineering and hydrology — location of dams, landslide monitoring, canal routing, runoff prediction, etc.

The most frequently reported achievement from ERTS of direct concern to geology has been its ability to reveal linear features on the earth's surface. The economic and practical aspects of increased knowledge of regional structural elements (principally, recognition of new lineaments and definition of their distribution patterns) are numerous. For example, some ore deposits are controlled by or associated with lineaments or circular structures. Fracture zones and joints, expressed as lineaments, are frequently avenues of groundwater flow and storage. Many lineaments are also loci of active faulting, and hence sources of destructive earthquakes. Other lineaments may be potential hazards in engineering projects and could affect mining operations, tunneling, dam safety, construction on slopes, and loss of gas in storage.

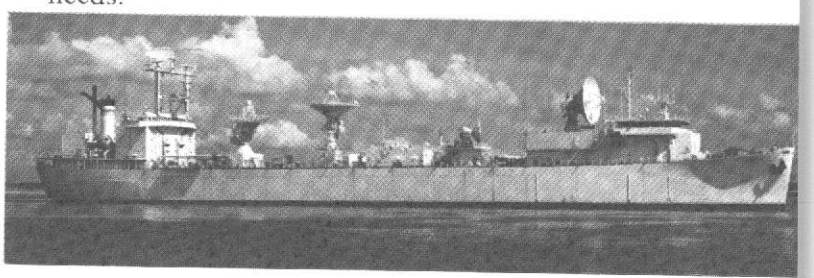
Water Resources: ERTS-1 water-resource studies have provided much more useful and applicable hydrological information than was generally anticipated before launch. Various land uses related to water-resource management can easily be identified and mapped using ERTS-1 data. By noting place and area, sources of water pollution, increasing sediment-load sources, and changing water yield can be delineated.

One example of water-resource management occurred in Arizona. The Verde River watershed in central Arizona furnishes municipal, industrial, and agricultural water to the Salt River Valley — an area that contains more than half of the state's population and about one-fourth of its irrigated land. When there is a possibility of exceeding the water storing capacity of reservoirs in the area, it is necessary to release water to prevent dam damage. This oftentimes causes flooding and, of course, wastes water. On February 21, 1973, area reservoirs had reached 95 percent capacity as a result of runoff from a general rain in the area during the previous 24-hour period. To determine whether it would be necessary to release reservoir water it was essential that an estimate be made concerning the amount of runoff that was coming from the upper snow-covered portion of the watershed.

ERTS-1 Data Collection System information was provided which indicated snow melt rate had not increased stream flow significantly, and water release rates from the reservoir could be minimized, thus reducing the amount of inconvenience caused by the necessary release of water while still maintaining a minimum safe margin of available reservoir storage to protect against major flooding.

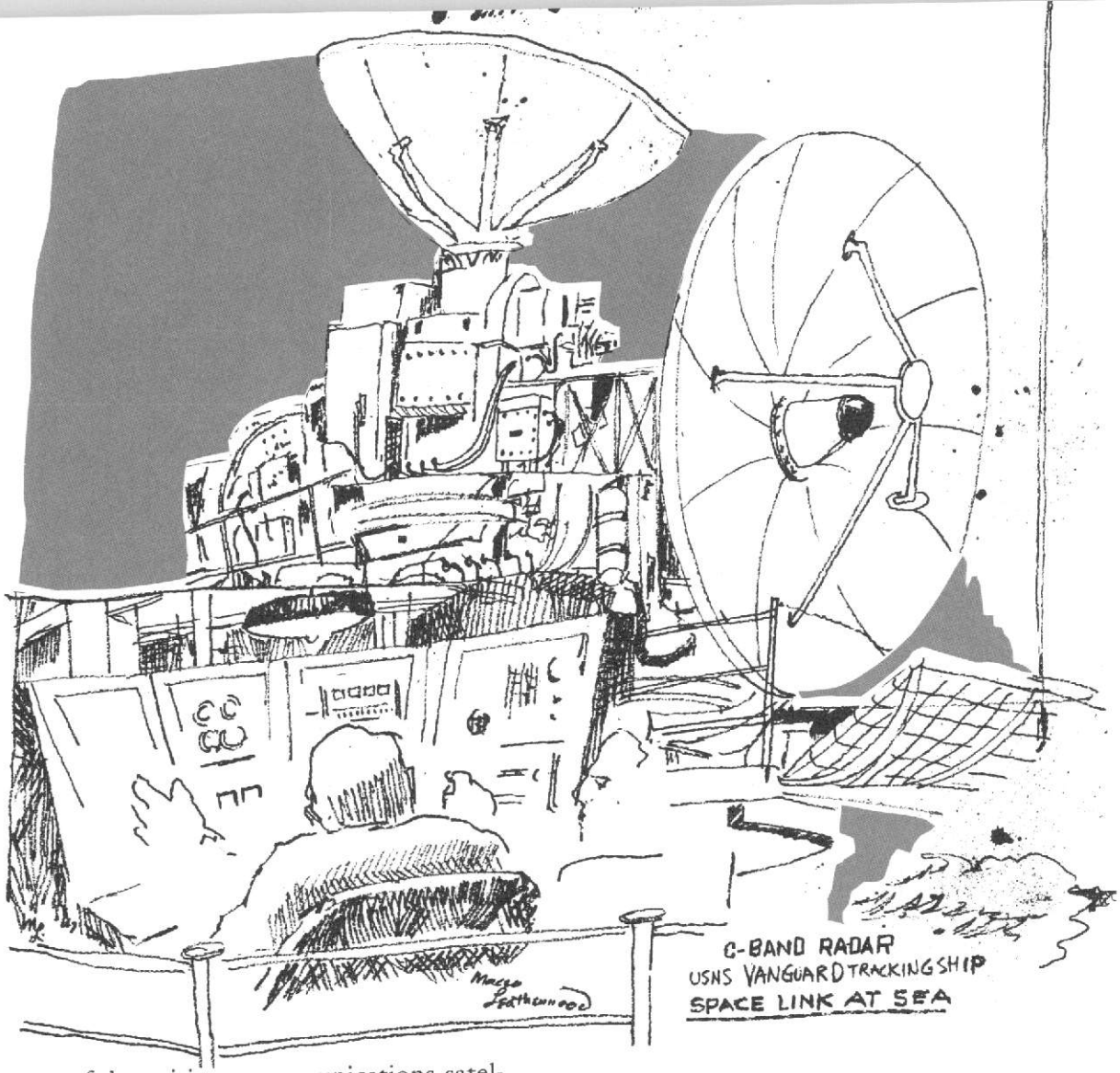
VANGUARD/PLACE EXPERIMENTS

Satellite communications for ships and aircraft have long been a subject of interest in civilian maritime and aeronautical affairs. For example, a forecast predicts that 30,000 worldwide maritime vessels, ships larger than 100 gross tons, will be at sea, simultaneously, by 1980. The requirement for ship-to-shore and shore-to-ship radio communications will be staggering; only a system of worldwide, geostationary-communication satellites, fixed in a 22,300-mile-orbit above the earth's equator, can cope with maritime communication needs.



USNS Vanguard

The requirement for satellite communication with oceanic aircraft is almost as great; for example, up to 250 civilian, high-speed aircraft will be crossing the North Atlantic Ocean region, simultaneously, by 1980. Satellite communications can determine the exact location of each ship or aircraft, within one nautical mile (n mi), a distance that is sufficiently accurate for the captain or pilot to execute evasive maneuvers to avoid collision.



A successful maritime, communications satellite experiment was directed in 1973 by Goddard personnel. For the first time in maritime history, a ship's position at sea was automatically fixed in real time by means of sidetone ranging, radio signalling from two geostationary communications satellites (NASA Applications Technology Satellites ATS-3 and ATS-5) (1967 – 111A and 1969 – 069A).

The NASA satellite communications experiment, known as the Vanguard/PLACE Experiment, accurately determined within two n mi the absolute, geographical coordinates of a ship at sea (NASA's ship, USNS Vanguard) by means of C-Band radio signalling from the NASA ATS-5 and ATS-3 geostationary satellites. In addition, reliable 2-way voice communications were continuously maintained, using this experiment, between the ship Vanguard and a shore-based terminal located at Rosman, North Carolina.

The Position Location and Aircraft Communications Equipment (PLACE) was designed for NASA's ATS-F communications satellite, scheduled for launch in mid-1974. The basic purpose of the Vanguard/PLACE Experiment was to obtain engineering data and practical experience for the ATS-F satellite communications experiment which will use maritime and aeronautical L-Band frequencies for communication with ships and aircraft.

The test results obtained from the Vanguard/PLACE Experiment firmly establish that the technical concept is valid for maritime and aeronautical, mobile-user surveillance (position fixing) and communications.

HET EXPERIMENT

In June 1971 the Department of Health, Education, and Welfare, the Corporation for Public Broadcasting, and the National Aeronautics and Space Administration announced an agreement to join in an experiment to test various educational and health applications of communication satellites. This experiment, called the Health/Education Telecommunication (HET) Experiment, will be conducted on ATS-F. Extensive Goddard planning and preparation activities were conducted in 1973.

NASA/GODDARD has responsibility for the satellite and provides access to the ATS ground station to support the experiment. All other transmitting and receiving facilities are the responsibility of the Department of Health, Education, and Welfare and the Corporation for Public Broadcasting. Goddard has also provided technical support to ensure total system compatibility and performance.

HET consists of six experiments covering three geographic regions. The Veterans Administration has ten VA hospitals in the Southeast and Middle Atlantic states participating in the experiment. Video signals originating from Denver will provide the remotely located hospitals, in areas such as Oteen, North Carolina, and Salem, Virginia, some of the same clerical and consultative facilities that big-city hospitals enjoy.

The University of Washington will conduct a "regionalized medical school," sending lectures and consultations to students and faculties in Omak, Washington, and Fairbanks, Alaska. The aim is to find out whether a satellite can offer acceptable "linkage" between established medical schools and universities in states having no medical schools.

In Alaska, the Indian Health Service will use the satellite to try to improve health information among the inhabitants of five communities. It will provide televised diagnosis and consultation with "local health professionals and village aides" and also offer direct health help to the people.

Other portions of HET are directed toward education. In Appalachia beginning in July 1974, schoolteachers in 15 communities scattered through eight states will get intensive training in reading instruction and in career-education training.

In the Rockies, about 7,000 junior high students will be exposed to daily career education courses, to help them choose life occupations and to prepare for them. These courses will be aimed at Chicanos and Indians, as well as blacks and whites.

In addition, each participating school will be equipped with a video-tape recorder that can be activated by a signal from the satellite. Teachers will be given a catalogue listing some 300 educational programs they can use in class. The teachers will make their requests to the control center in Denver, which will, via the satellite, feed out the programs during the night. The automatic equipment will record the material for playback the next day.

In Alaska, 17 localities will be on the receiving end of "early childhood language development" and "basic English oral communications" projects. In other words, the satellite will be trying to teach people how to speak and write more effectively. Between times, some Public Broadcasting System programs and a taped "Alaskan Native Magazine" will be sent into the remote villages.

GARP

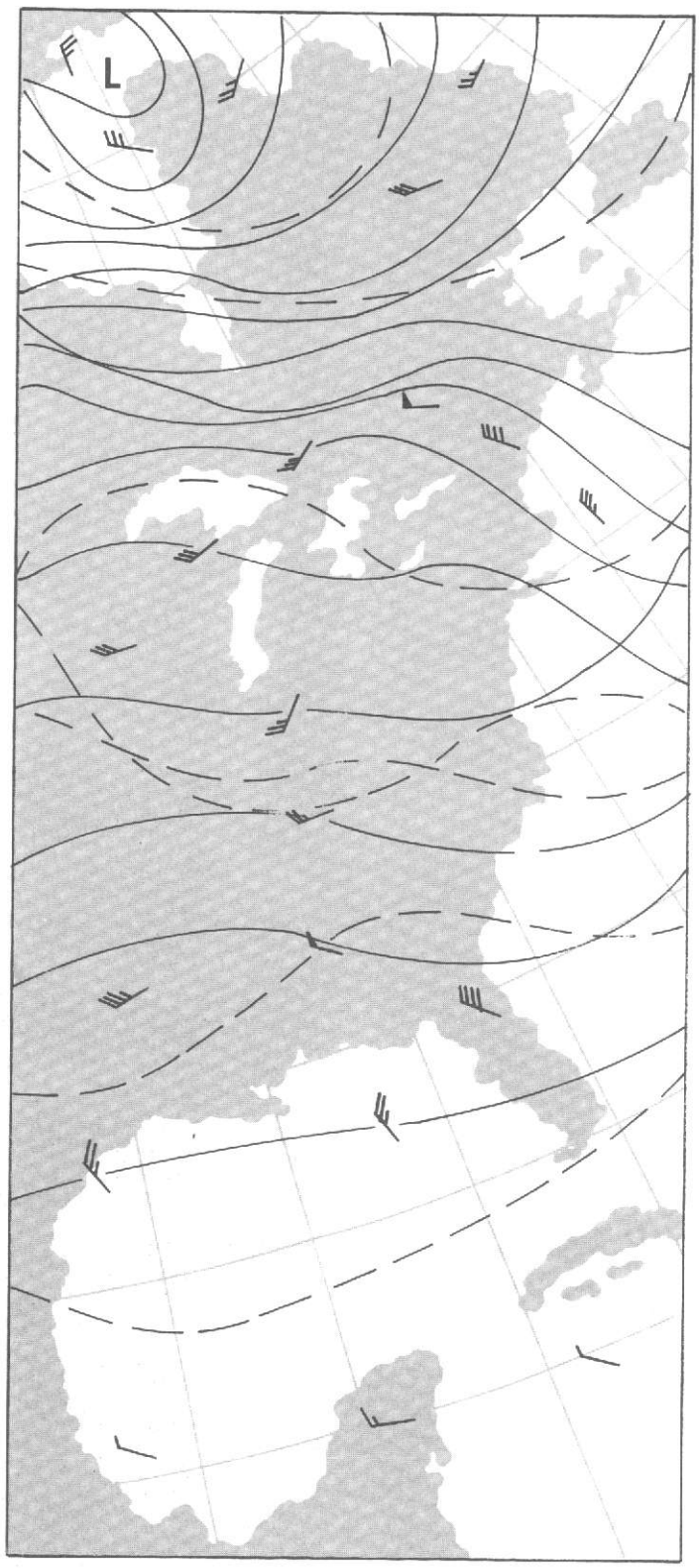
The Global Atmospheric Research Program (GARP) is an international effort to enhance the understanding of, and ability to predict, weather. It is jointly directed by the World Meteorological Organization and the International Council of Scientific Unions. The program originated with a declaration by the United Nations in 1961 that marked progress of importance to meteorological science had occurred as a result of advances in space and that world-wide benefits could be derived from international cooperation in weather research and analysis. There are two major objectives of the GARP program. The first is to improve understanding of the atmospheric processes involved in weather. The second is to improve the observing and computing systems used for weather prediction so as to extend the period of time for which valid weather predictions can be made. A key focus of the program is the First GARP Global Experiment (FGGE) which is currently scheduled for the end of this decade. FGGE will be the largest and most complex international cooperative space effort yet undertaken. It will involve five geosynchronous satellites and at least four polar orbiting spacecraft which will be launched by the European Space Research Organization, Japan, Russia, and the United States. More than twenty countries have volunteered supplementary facilities for use in FGGE. Prior to FGGE there will be a series of limited scale international experiments to explore various theoretical questions associated with GARP. One of these is the GARP Atlantic Tropical Experiment (GATE) which will occur in the summer of 1974. NASA is providing a research aircraft for use in GATE and will provide measurements of wind derived by special processing of spacecraft pictures of clouds in the GATE area.

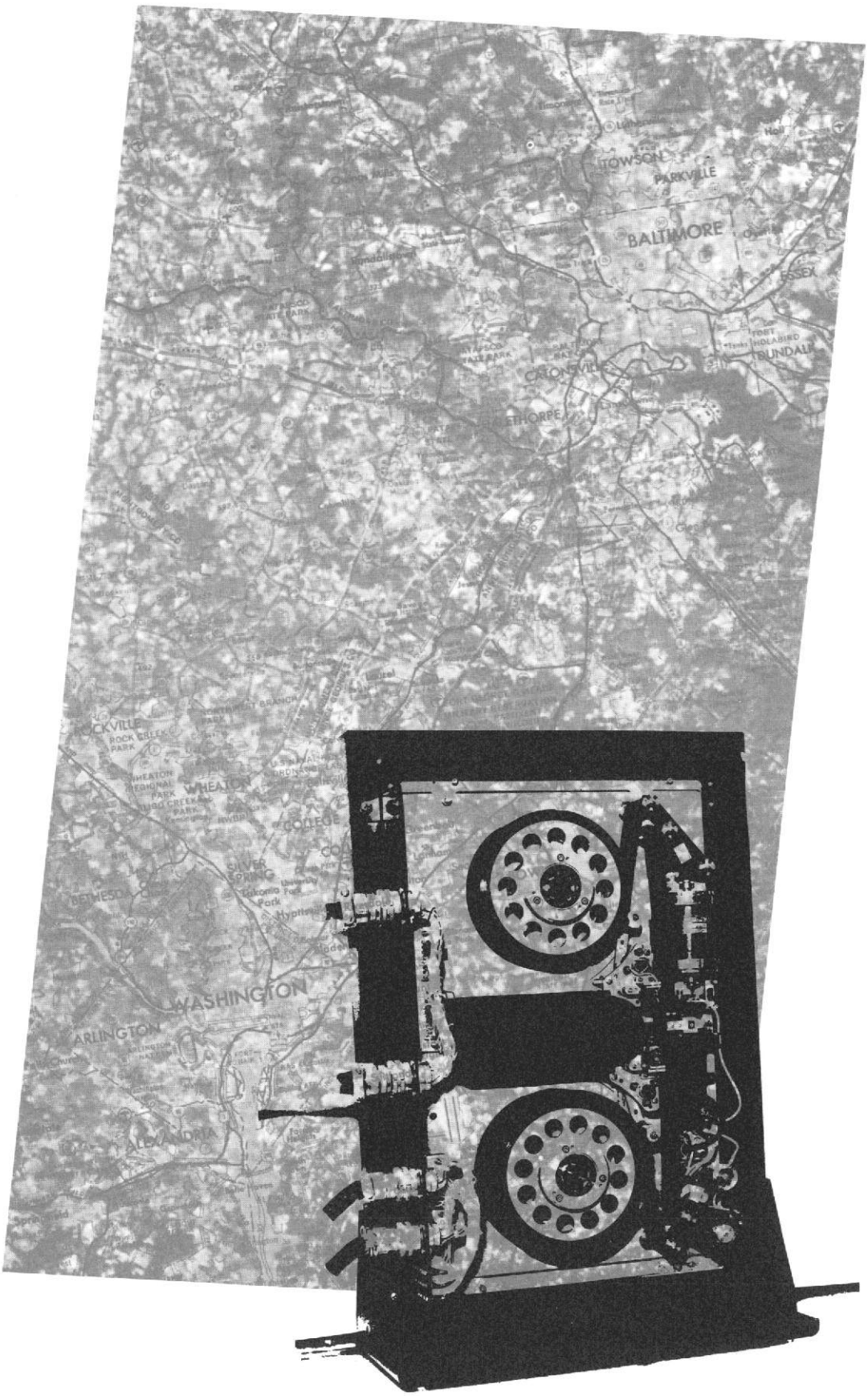
There is no precedent for FGGE in terms of the questions of data volume, communications requirements, operational considerations, or computer processing all done in near real time. Therefore, NASA has initiated a Data Systems Test (DST) which combines operational and research satellite data with data from special observing systems similar to those proposed for FGGE. Thus the Data Systems Test, which will be run in 1974 and 1975, will serve as a prototype for FGGE and will help to uncover and resolve problems for FGGE.

The past year, 1973, has been spent in planning DST itself and in starting a series of applications research projects to be used for the test. The Goddard Institute for Space Studies has been developing methods for directly inserting spacecraft data into global weather models and for increasing the density and accuracy of atmospheric temperature and humidity profiles derived from spacecraft data. NASA also has three cooperative projects with the National Oceanic Atmospheric Administration to automate the estimation of wind velocity from spacecraft pictures of cloud motions, to develop numerical models for global weather analysis and forecasting, and to improve methods for determining atmospheric temperature profiles from spacecraft measurements of radiance.

NASA and the National Center for Atmospheric Research are developing a new concept for obtaining wind, temperature, and humidity profiles in the equatorial region. This is to launch large (20-meter diameter) carrier balloons which will rise to an altitude of about 24 kilometers and then drift around the earth in the equatorial zone. At selected locations over the oceans and in uninhabited land areas the balloons will receive commands to drop instrumented sondes which will measure the desired data. The balloon receives its command from, and relays the sonde data to, the synchronous spacecraft which are in orbit over the equator. A fleet of several hundred of these carrier balloons is planned for the First GARP Global Experiment. The concept will be tested by building and launching twenty carrier balloons during DST.

Thus, 1973 was a year in which the GARP Project initiated several major activities with the final objective of improving weather prediction. Most of this first development phase will be completed in 1974, and the various items will be critically tested in the Data Systems Test during 1975.





ERTS-1 Wideband Video Tape Recorder

SPACECRAFT TECHNOLOGY

Spacecraft technology development at Goddard covers a full spectrum of activities, through component, system, and subsystem design to direct support of projects. One of this year's most gratifying highlights was the designation of Goddard to serve as Agency "lead center" for tape recorders. Efforts also continued in all areas of electronic and mechanical component development, materials engineering, structural analysis, and power systems.

GSFC TAPE RECORDER LEAD CENTER ASSIGNMENT

NASA has initiated a program directed to improving the reliability and decreasing the cost of spacecraft components through "standardization." Herein, one design, or a small family of designs, will fulfill the requirements of many flight programs, instead of the development of unique equipments for each program as in the past. More use of the same design will decrease the cost for development and for recurring unit costs as well as improving reliability. These "standardizations" will be established by the determination of future needs and the development of baseline design requirements by NASA-wide committees followed by the designation of "lead centers" for implementation.

The first components to be standardized are spacecraft tape recorders. A committee known as the Tape Recorder Inter Center Panel determined future needs and described a family of two recorders with capacities of 10^8 and 10^9 bits. A device with a capacity of 10^9 bits would have been sufficient for nearly all prior NASA programs. The Goddard Space Flight Center, due to its extensive background in this area, has been named lead center for spacecraft tape recorders. In addition to an in-house 10^8 bit engineering model recorder development, GSFC has prepared specifications and initiated a procurement for standard recorders in the two sizes. This buy includes flight recorder requirements for the first two user programs – NIMBUS-G and the Shuttle.

ERTS – WIDEBAND VIDEO TAPE RECORDER (WBVTR) SETS RECORDS

Images from the Earth Resources Technology Satellite can be received "real time" while over North America. For most of the earth, however, the data must be stored on-board and played back when the satellite is over a North American ground station. These data are produced at rates higher than on any previous NASA spacecraft. Inputs are accepted either from the return beam vidicon camera in a 4 MHz analog form or from the Multispectral Scanner at 15 Megabits per second.

The ERTS-WBVTR is the first spacecraft recorder ever to accept such rates and has set the following records:

- Highest rate digital data spacecraft recorder ever built (15 Mbs.).
- Longest life of any spacecraft rotary head recorder (nearly 1000 operating hours over 20 months – prior recorders had never achieved greater than approximately 100 hours).
- Most digital data ever stored and/or reproduced on a spacecraft tape recorder. (Nearly 2×10^{13} bits – more than 10 times the data stored on all previous NASA spacecraft tape recorders.)

MAGNETIC BEARING TECHNOLOGY

Magnetic bearings reached a new plateau of development early in 1973 with the operation of a magnetically suspended momentum wheel with 356 N (80 lb.) load capacity. This engineering model represents the realization of a completely non-contacting rotating system capable of providing an essential spacecraft function with no speed-dependent life limitations. [The design removes operation limitations caused by lubrication or environmental (thermal, vacuum, zero g, etc.) considerations.]

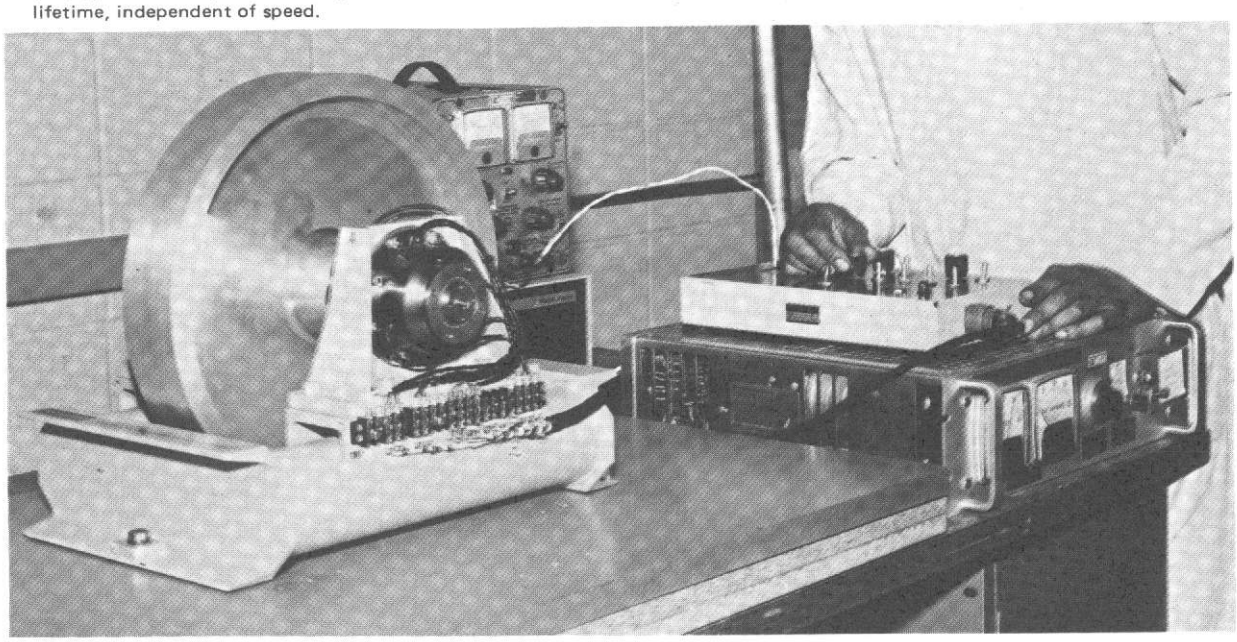
Samarium cobalt magnets are used with radial servo control to provide free rotor support in all axes with a minimum of power. Axial centering 1,750 N/cm (1,000 lb./in.) is passive — no power required. The rotational drive is provided by an efficient brushless dc motor to 4,800 RPM providing 80 Nm-sec. (60 ft.-lb.-sec.) momentum. The torque requirement for this design is about 25 percent of that using precision ball bearings.

Work of a more fundamental nature, with a practical result, was the completion of a computerized analysis of magnetic bearing design and dynamics including non-linear magnetic field analysis.

The significance of this work, toward the goal of indefinite life for mechanical systems in space, was recognized and considered in several NASA developments. Energy storage system Integrated Power and Attitude Control (IPAC), experiment isolation and fine pointing (Shuttle), as well as attitude control (despun systems) and scanners are prime candidates to benefit from this technology. Also, an interagency development, the Annular Momentum Control Device (AMCD), was undertaken with the Langley Research Center. This task is the development and fabrication of a two-meter diameter wheel to be magnetically supported and driven at its periphery.

The AMCD is to be a 4,000 Nm-sec. (3,000 ft.-lb.-sec.) wheel, with the potential of providing a low cost alternative attitude control system for large vehicles of the space station size. The year 1973 saw this effort reach the design review and approval for fabrication stage, as well as the successful operation of a small 0.4 m (16 inch) diameter demonstration rim-supported model.

This photograph shows an engineering model momentum wheel suspended by magnetic bearings. The momentum wheel rotor is magnetically suspended at each end so there is no physical contact between the rotor and the support structure. This system can operate directly in a vacuum environment without lubrication and has a virtually unlimited operating lifetime, independent of speed.



ADVANCED INSTRUMENT MOTOR AND SPEED CONTROL

The in-house development of a high performance, electronically commutated dc motor and direct-drive "phase-lock" control system has been accomplished. This system meets all performance goals for the capstan drive of the proposed family of NASA standard tape recorders.

There are, of course, a large number of different types of motor speed control systems presently in use which, in general, adequately serve the function for which they are designed. However, conventional systems do suffer certain disadvantages, particularly in areas such as ultra low-speed operation, extremely extended speed range, size, weight, and power consumption.

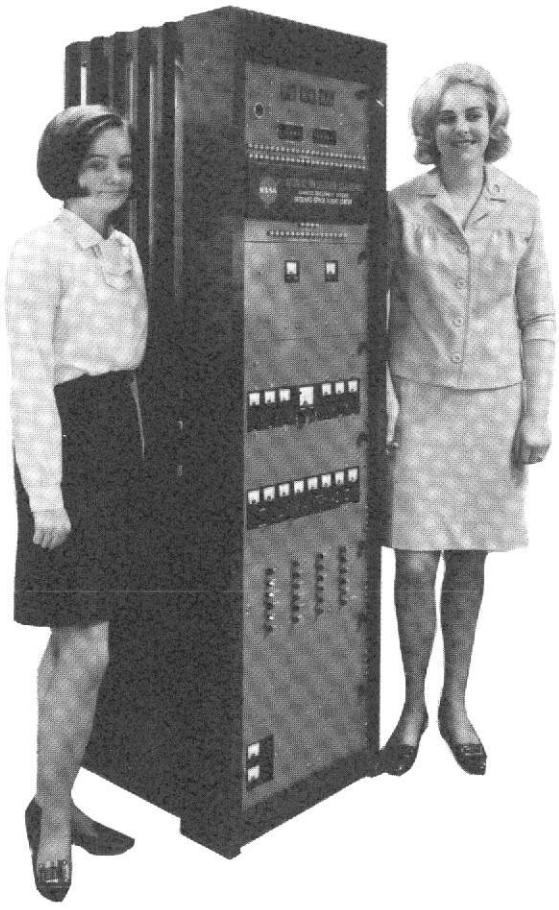
The new GSFC speed control system overcomes or substantially reduces the limitations of prior systems. For example, the system is self locking and uses an optimum error signal demodulator with an automatic gain control. Mechanization of the above is such that stable operation at any desired speed over a range of 160 to 1 can be commanded simply by changing the reference frequency.

ATOMIC HYDROGEN MASER TIME AND FREQUENCY STANDARD

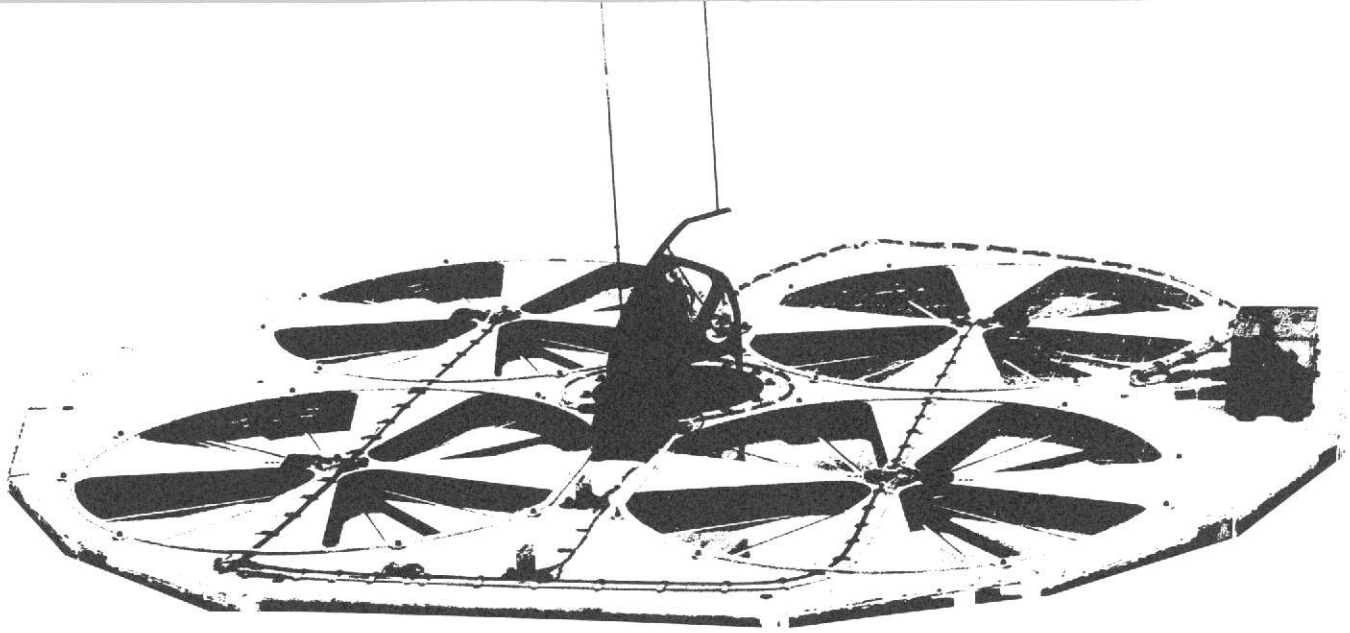
First operation of a new design atomic hydrogen maser standard was achieved in 1973. With stability measured as a few parts in 10^{15} fractional variation, this is the world's most stable atomic standard device. By using improved concepts in atomic beam focussion geometry, the new maser exhibits a factor of ten higher atomic oscillation level than past devices, yet it is more efficient in operation, as well as less sensitive to adverse environmental influences; thus, greatly increased operational life as well as improved performance has been obtained.

The stability of the basic atomic frequency and time standard source is of paramount importance in planetary and spacecraft position and trajectory measurements, in the resolution of astro-physical and geodetic phenomena by radio interferometry, and in the worldwide dissemination of precise and accurate frequency and time for many earth-bound applications of fundamental importance.

The new maser has excited the interest of many scientists, both nationally and internationally, and with urging from several potential users both within NASA and in the scientific community in general, the possibility of stimulating industry to produce standards of the present design is being investigated.



Atomic-Hydrogen Maser Time and Frequency Standard



AE-C Feedback Controlled Louvers

NICKEL BRAZE SEALS

Hermetic seals and, in particular, ceramic-to-metal seals have been a major problem when applied to batteries. The age-old corrosion problem of dissimilar metals in a strongly conductive electrolyte with a voltage impressed across the metals plagued the early seals (1960). In fact, in the early sixties, as many as ninety percent of a production lot developed leaks at the ceramic to metal seals. During the mid-sixties some improvement was attained by isolating both terminals of the battery cell and coating the metal surfaces. True, the seal production yield was of the order of ninety-eight percent but eventually the protective coating would develop imperfections, and leakage would commence.

During 1970, in a cooperative effort with General Electric and GSFC, a program was initiated to investigate the long-term cycling and temperature effects on a ninety-nine percent nickel braze ceramic-to-metal seal. Six ampere-hour General Electric cells have been cycled with these seals under stressful conditions or orbit time and temperature from 1970 through 1973. No leaks have occurred. Others (TRW, Hughes) who have used the seal on NASA and Air Force programs have reported excellent results. General Electric has used the GSFC cycling information to justify using the seal on heart pacer batteries.

SPACECRAFT DYNAMICS

Gravity-gradient Stabilization: An historical milestone was established when the Radio Astronomy spacecraft was put in orbit around the moon, not only in a scientific radio astronomy sense, but also in a technological gravity gradient stabilization sense as well. A spacecraft, with antennas, when deployed, longer than the Empire State Building is tall, used the moon's gravity field to orient itself along the orbit local vertical so that the radio-astronomy science mission could be carried out. The spacecraft consisted of a central cone with four deployable antenna booms in an X configuration (two antennas back to back) with a nominal 60 degree included angle plus a libration damper skewed 65 degrees from the plane of the antenna booms. The maximum length of each antenna is 750 feet, and the libration damper booms are 315 feet each. The primary antenna which forms the X is made from berylium copper material nominally 0.002 inches thick. The booms are highly polished silver-plated, perforated, interlocked 0.58 inch diameter tubes. When not deployed, each antenna boom is rolled up in a mechanism 16 x 8 x 6 inches. The success of the lunar gravity gradient stabilization was made possible in part by an elaborate flexible spacecraft computer program which indicated the conditions under which stabilization was possible.

Spin Stabilization: The last spacecraft of the Interplanetary Monitoring Platform series, IMP-J, launched in October 1973, deployed an electric field measurement experiment which consisted of two wire-elements, each 197 feet long and approximately 400 feet tip to tip. This was over three times the length of any wire elements previously deployed. The IMP-J spacecraft was spin stabilized at 23 RPM thus providing the centrifugal restoring force for the wires. A novel application of a fluid ring damper damped the excess motion of the wires caused by the deployment and orbital environment disturbances. The spacecraft attitude motion was stable in all respects as theoretically predicted. Because of their extreme light weight and no buckling mode of failure, the wire electric field sensing elements enabled the scientist to use longer lengths (and hence more sensitive experiments) than would have been possible with conventional semi-rigid booms.

MATERIALS ENGINEERING

New Plating Technique: A novel "peen plating" technique has been developed which entails a process by which metal powders are mechanically plated onto metal and ceramic substrates by the impact action of small glass beads that are propelled by an air stream, the stream of metal powder and stream of glass beads being either separate or incorporated as one. By this method, the low elastic modulus metals, such as aluminum, are rapidly plated onto the substrate without the use of hazardous chemicals or expensive equipment. The process has generated much interest in the metals finishing industry such that several hundred companies have contacted GSFC for information about it. Preliminary investigation suggests that such other metals as tin, lead, zinc, solder, and cadmium will be able to be peen plated very easily, and that the metals with higher elastic moduli, such as nickel, copper, and chromium, may plate out with more difficulty.

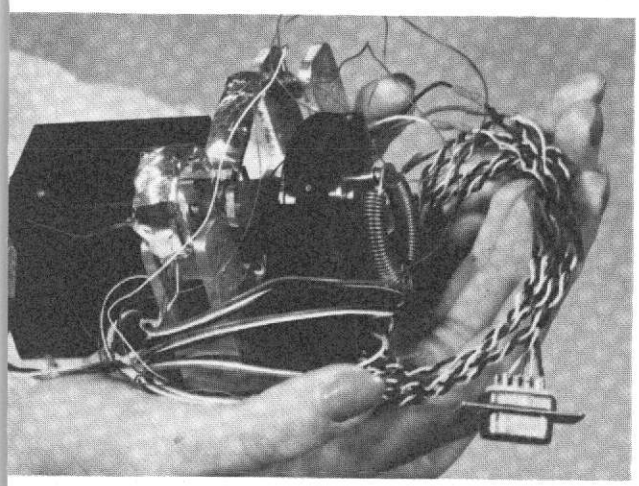
By this process, it is hoped that simultaneous achievement can be made of mechanical property improvement due to the peening action and physical property improvement (electrical, thermal, or chemical) by virtue of the plating metal selected.

Metal with a Memory: One of the first practical space flight applications of Nitinol, the alloy with a thermal memory, is the development of an actuator to rotate a fluxgate magnetometer sensor assembly aboard the Mariner, Jupiter-Saturn-77 spacecraft. Nitinol, a non-magnetic alloy of nickel and titanium, was developed some ten years ago by Buehler and Wiley of the U.S. Naval Ordnance Laboratory.

The memory of this unique material is such that it will restore itself to its original shape when heated, even after being "permanently" deformed out of shape.

In returning to the original shape, initiated by heating the alloy to a moderate temperature, considerable force is exerted. It is this mechanical force that provides the basis of the new design.

Two Nitinol leaf springs, when alternately electrically heated, provide cyclical bi-



A bench model of the Nitinol actuator is held by a Goddard secretary. The Nitinol leaf springs are alternately heated electrically and, through a bell crank mechanism, flip a rotor shaft back and forth through a 180° arc.

directional rotary forces, which flip a magnetometer ± 180°. These springs will drive with 45 inch-ounce of torque at less than eight watts of power for periods up to five years. This mechanism can be enclosed in a volume of eight cubic inches, and it weighs less than 0.5 pounds.

In tests it has been continuously cycled over 2,000 times, ten times the cycles required for flight. This new actuator concept, more than any other known device, satisfies the constraints and requirements imposed by this application.

THERMAL STRUCTURAL ANALYSIS

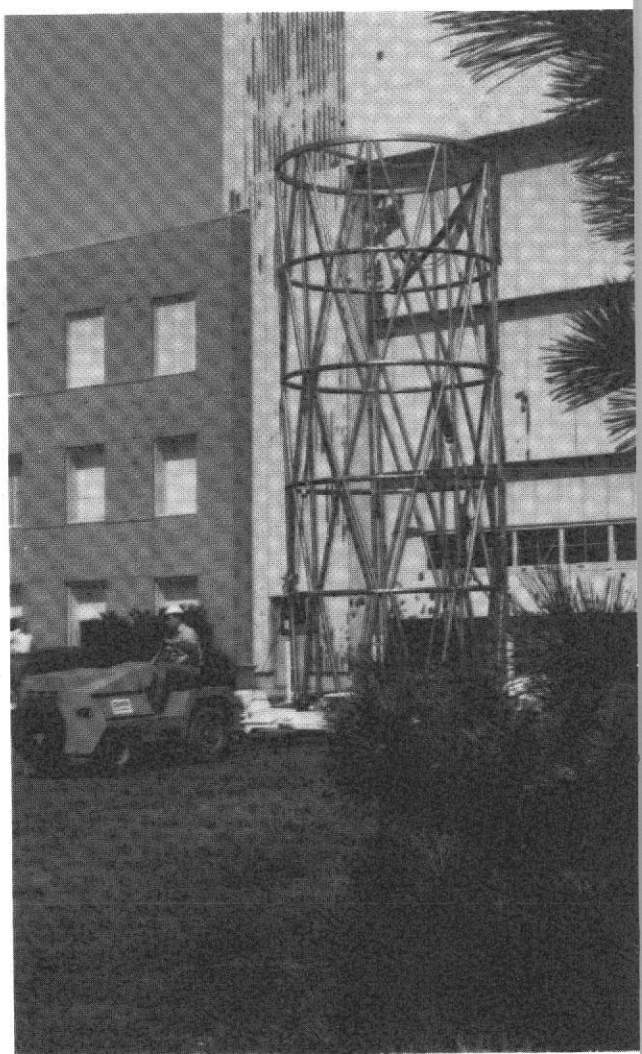
A low-cost, high-accuracy method has been developed for simulating and predicting the behavior of large support structures subject to complex thermal loadings. Accurate information of this type is invaluable for the construction of orbiting optical systems which undergo thermal variations as a result of their rotation about the Earth.

The structure chosen for this development was the tubular titanium spaceframe built as the engineering model of the Secondary Mirror Support for the Large Space Telescope. It is 120 inches in diameter and 311 inches high but weighs only 2,200 pounds and is, to the best of our knowledge, the largest all-welded titanium alloy structure in existence. A NASTRAN (NASA Structural Analysis) mathematical model was constructed to simulate the test specimen.

The physical tests and analytic simulations were performed simultaneously, the results compared and refinements made to both the test and analytical techniques.

Heat tapes and precision thermistors were strategically located along three of the structure's nine vertical columns. Additional thermistors were located on one of these columns to determine its transverse thermal profile. This is of utmost importance as the thermal gradients induce bending in the members which must be considered. The instrumented structure was placed under vacuum in order to reduce thermal variation caused by air currents. Two extremely accurate laser interferometer systems were located in vacuum protection boxes adjacent to two of the heated columns to measure their vertical displacements.

Various voltages were applied to the heat tapes, while the thermal and dimensional data were automatically recorded every hour. A computer program was written to compile the raw data and compute average element and column temperatures, as well as evaluating the double integrals required to compute the



Space Telescope Structure on its Way to Structural Stability Test Area

thermal gradients. This program instructs the computer to punch the necessary "load" cards which are applied to the NASTRAN Model.

Computer simulations of three different test days at different thermal loads have been completed. In all cases, the computer-predicted results have been within minus seven to eight percent of actual test results. The repeatability of these tests and results has been outstanding, leading to a very high confidence factor.

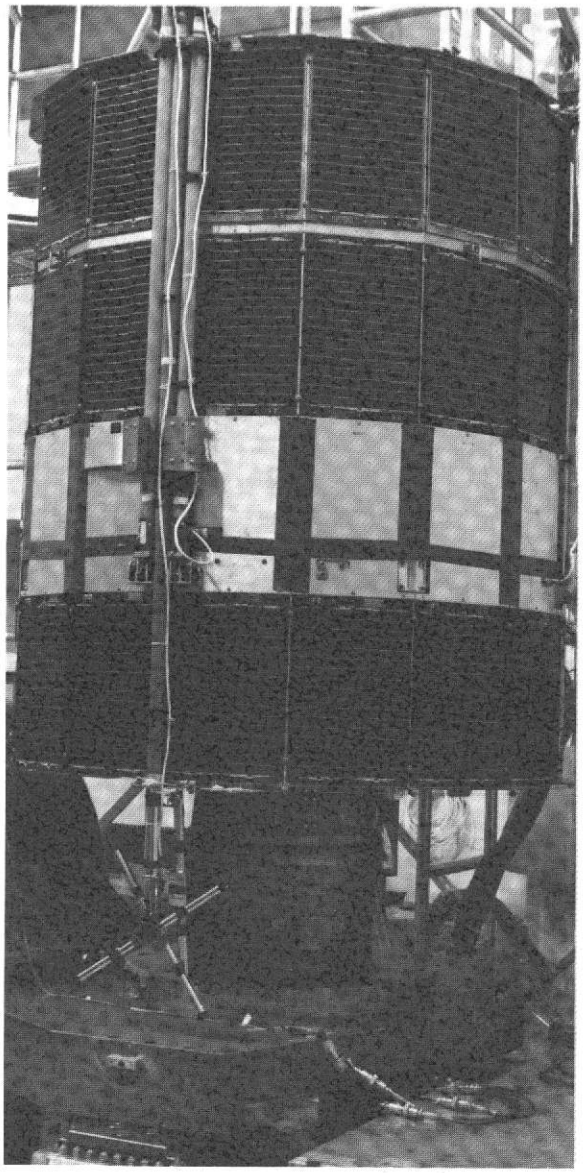
In this manner, complex thermal loadings can be handled without incurring the high costs involved in testing. This modelling procedure can be applied to advantage for such missions as the LST, IUE, EOS, SMM, and others where precise alignment is required.

IMP-J VIOLET SOLAR CELL PANEL

The first solar cells were made in the early fifties. These were the earliest devices that could turn sunlight directly into electricity at efficiencies greater than one percent. These cells operated at about five percent efficiency, which is to say that five percent of the sun's energy striking these devices was converted to electricity. By the time of the early space program, efficiency of the cells had advanced to a ten-to-eleven percent efficiency. Throughout the sixties and to the present, solar cells of these efficiencies have powered practically all of NASA's satellites.

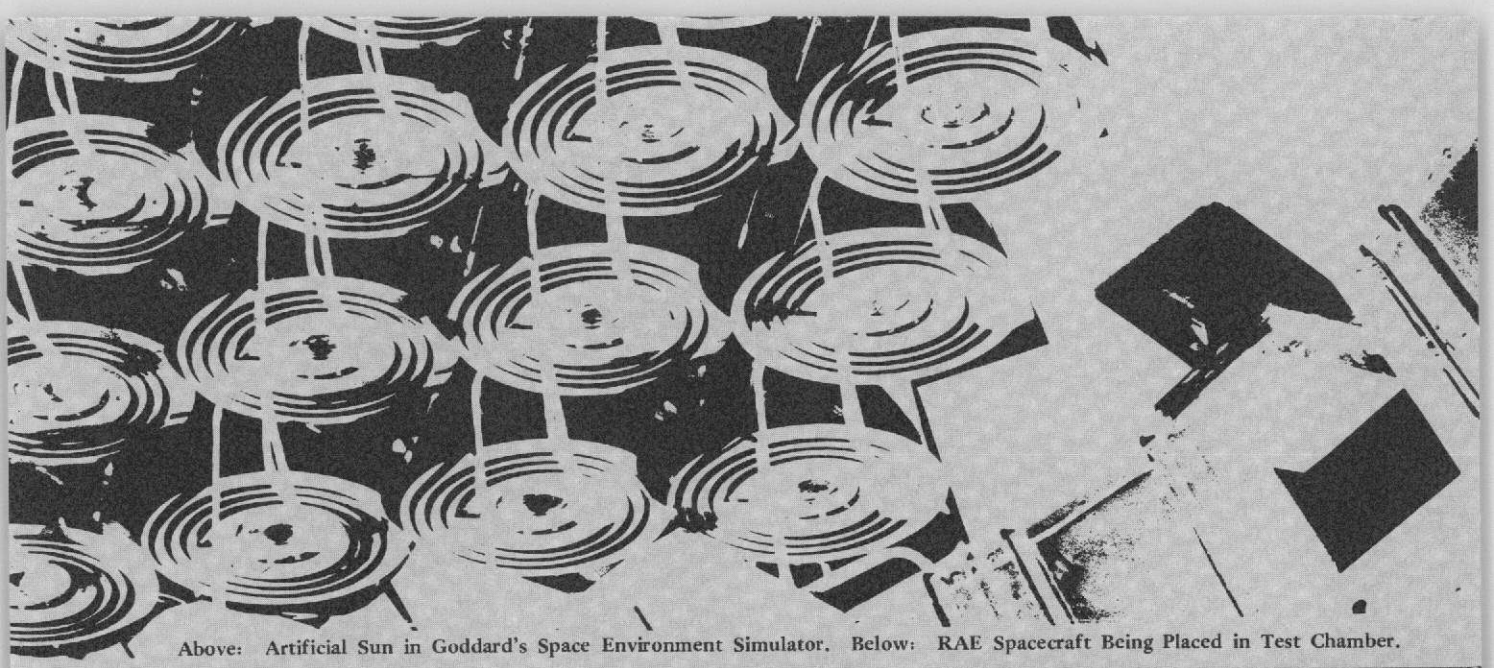
In the early seventies, Dr. Lindmayer, then of COMSAT Laboratories, developed the so-called "violet solar cell." This cell represents a large advance in solar cell technology. Indeed, the violet solar cell has produced efficiencies in excess of fourteen percent for space applications. The flight of a violet solar cell panel represents a significant step in proving out this recently developed device.

Goddard Space Flight Center was fortunate in obtaining early samples of these solar cells.

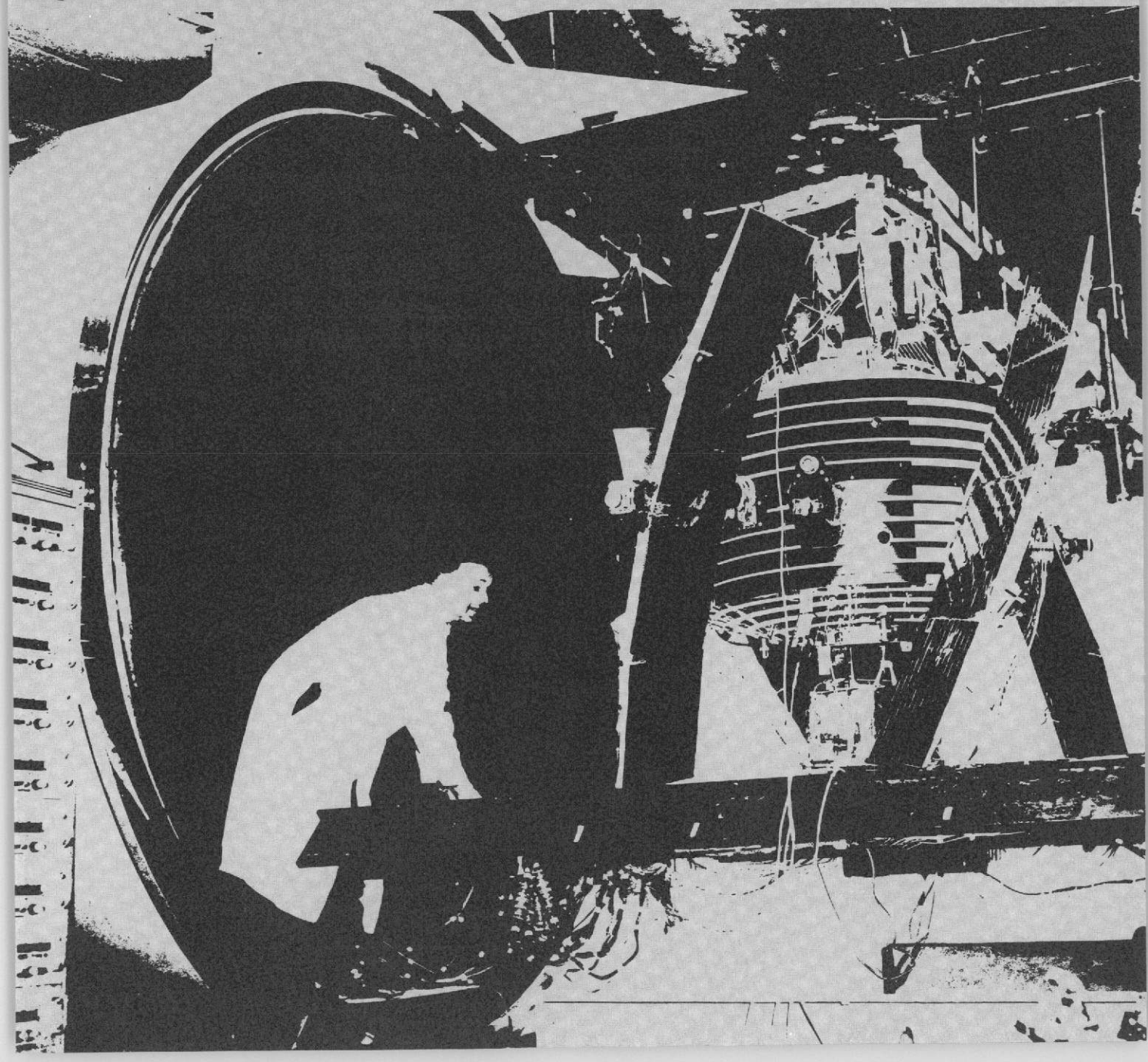


The cells were mounted on a solar panel by COMSAT Laboratories and flown on the IMP-J satellite. The cells and the panel were qualified for space flight use by Goddard Space Flight Center. The results of the qualification tests and the output of the IMP-J panel, as measured in the space environment, have shown that the violet cell will produce at least twenty-one percent more power than conventional cells.

It is now certain that these new cells and other recently developed high efficiency cells will be used to power future NASA spacecraft.



Above: Artificial Sun in Goddard's Space Environment Simulator. Below: RAE Spacecraft Being Placed in Test Chamber.



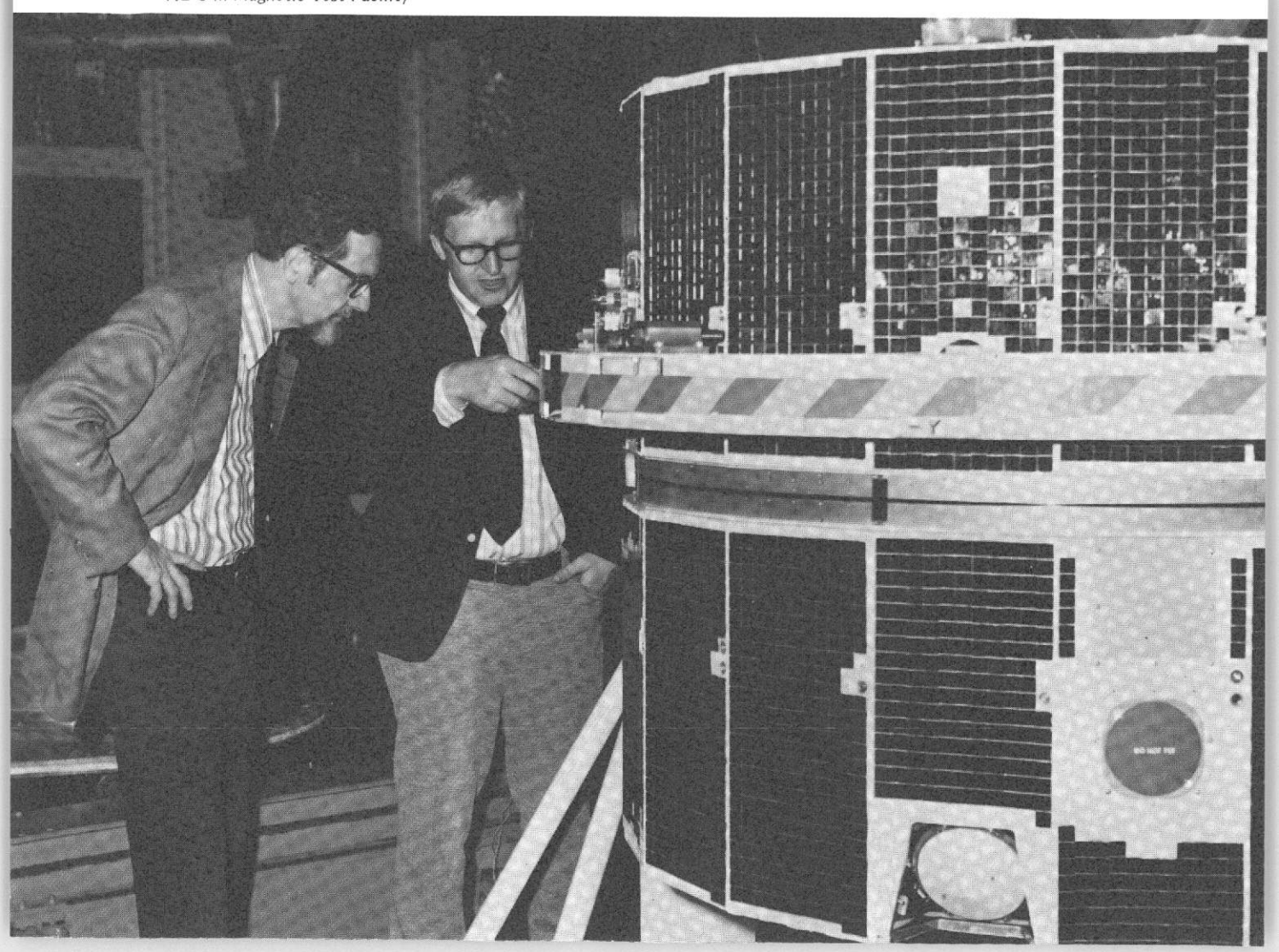
SYSTEMS RELIABILITY

The successful launch of two particular GSFC spacecraft in 1973 was welcomed with special satisfaction by the Goddard test and evaluation engineers. The Radio Astronomy Explorer-B and the Interplanetary Monitoring Platform-J both were tested in-house and achieved mission success. The two spacecraft brought the total tested in-house to 31 with the mission success record continuing at 100%.

During 1973 techniques learned over the last 13 years were sharpened to advance the art of spacecraft reliability despite having entered an era of increasing budget constraints. Some of these techniques and their use in the effort to deal with cost restrictions are highlighted in the following paragraphs.

Qualifying AE-C Experiments Using Spacecraft Simulators: During 1973 a spacecraft simulation system of Goddard design was used to evaluate the electrical performance of some 19 different types of experiments and engineering measurement devices for the Atmospheric Explorer-C spacecraft during environmental test operations. The computer-controlled simulators automatically ran the test operations, reproducing all spacecraft command and data handling functions and interfaces, such that the experiments experienced all electrical conditions normally present during orbital command and data handling operations. The system was made up of a Sigma 5 computer serving as the central control and data processing system and Goddard-designed software programs to provide fast, automatic, functional checkouts of the experiments.

AE-C in Magnetic Test Facility



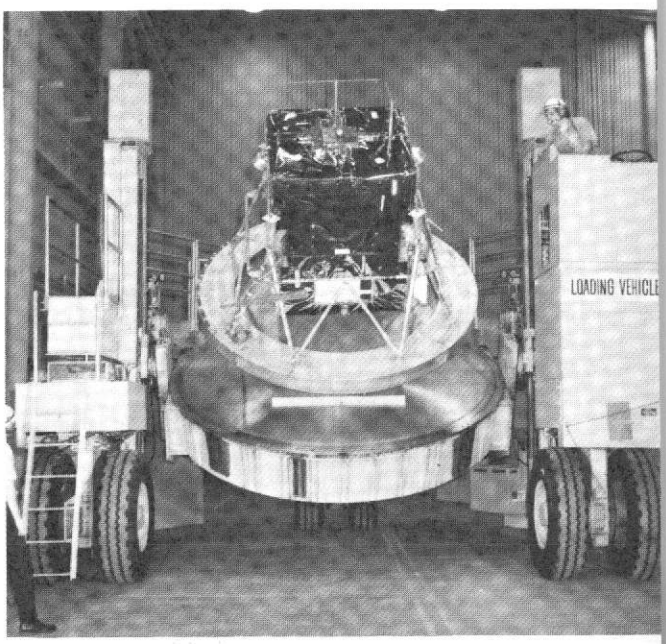
A few of the more important benefits of the system are: excellent validation of the experiments under tight budget constraints; avoidance of launch schedule delays by combining functional validation with environmental testing; early detection of spacecraft/experiment interface problems, avoiding costly delays during spacecraft integration by the prime contractor; development of software programs which were also directly usable by the prime contractor; and development of a technique which will be adaptable to full systems level testing in the future.

Multidiscipline, Analytical Evaluation: During the year a multidisciplinary approach was applied to identify potential space hardware problems before the hardware was built. The fully organized technique was first applied on optical experiments for the Orbiting Solar Observatory-I and the International Ultraviolet Explorer spacecrafts. A number of deficiencies were uncovered, including one that could have made a solar experiment on OSO-I inoperable.

The technique, which is being broadened in its use, also provides better definition of test conditions; evaluation of hardware under conditions that cannot be simulated, such as zero gravity; extrapolation of test results to unmeasured conditions; and verification of analytical models to simulate orbital behavior.

The technique requires the coordinated use of three major ingredients: (1) a team assembled from the various analytical engineering disciplines; (2) maximum use of computerized modeling and numerical analysis; and (3) testing of hardware models to verify and refine the analytical modeling.

Success of the approach has encouraged expanded application in a full systems level evaluation of the Earth Observatory Satellite.



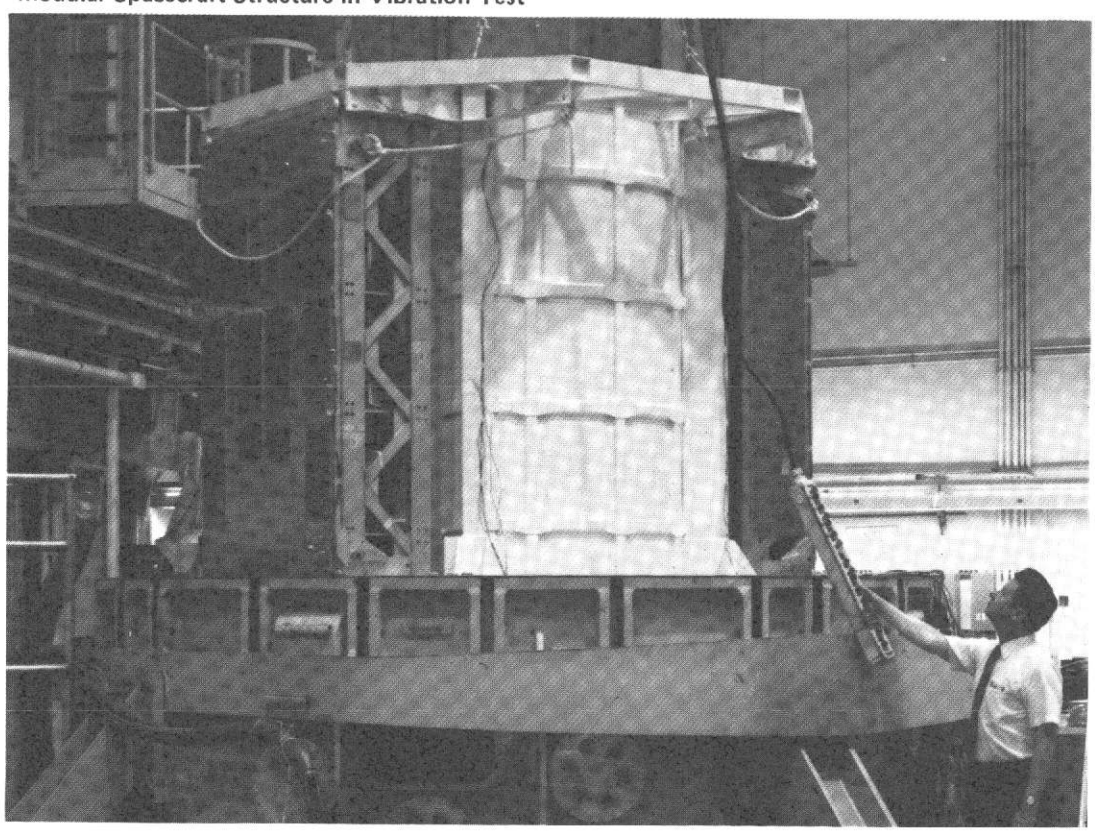
ATS-F on Launch Phase Simulator Equipment Handling Vehicle

Cost-Effective Use of Existing Facilities: The Goddard Launch Phase Simulator (LPS) rotunda was converted into an acoustic test chanber large enough to accommodate all of NASA's present and proposed spacecraft including those to be carried aloft by the Space Shuttle. The Applications Technology Satellite (ATS-F) is expected to be the first spacecraft to be tested in the chamber.

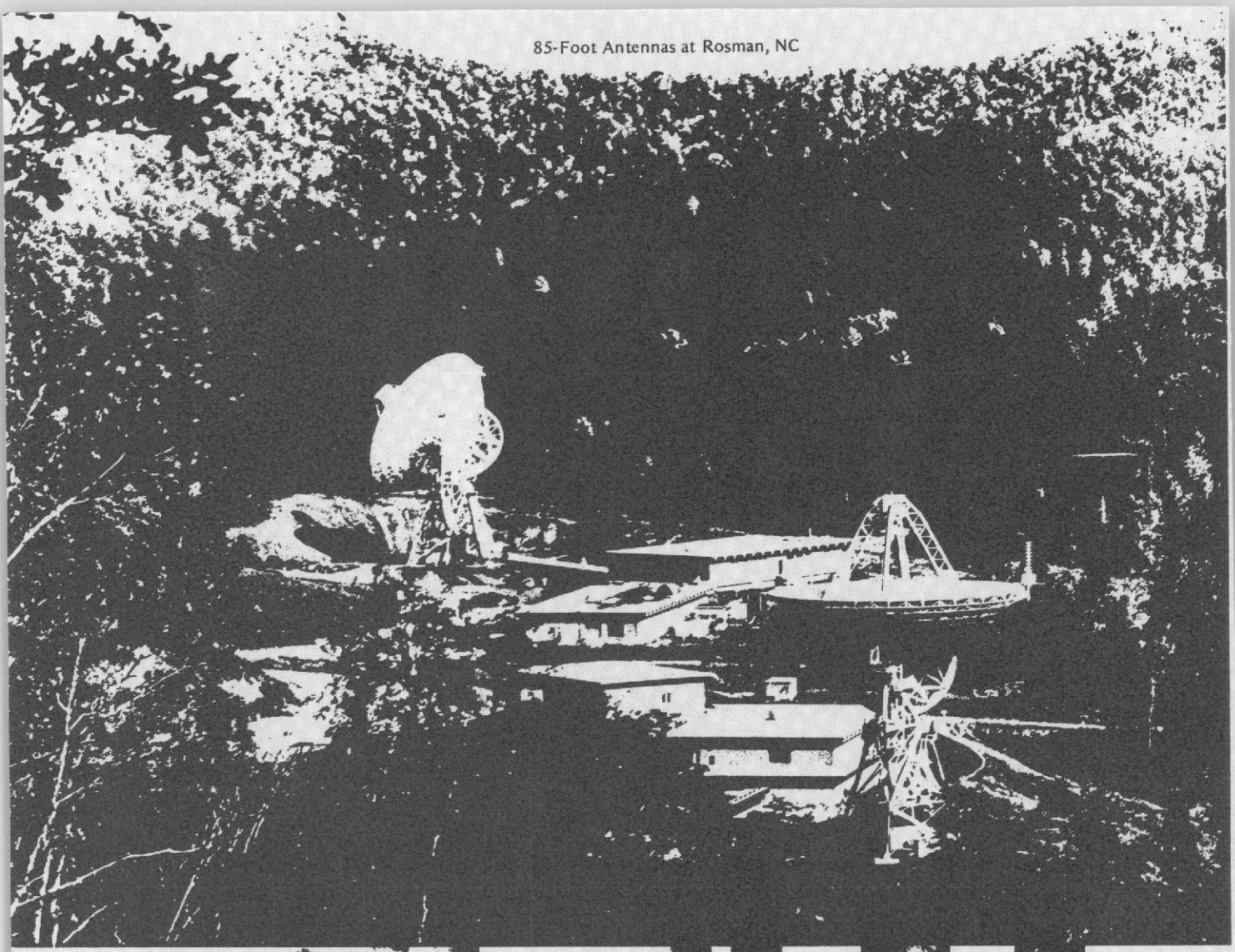
Previously it had been thought that large cylindrical chambers such as the LPS rotunda (157 feet in diameter by 27 feet high) could not be used satisfactorily for simulating the acoustic vibrations to which a spacecraft is subjected during launch. Acoustic engineers, drawing on previous testing experience with smaller cylindrical chambers, analytical studies, and tests on the rotunda itself, determined that the rotunda would make a good reverberation chamber. All that was required was a large, off-the-shelf, efficient noise generator.

Solutions to Project Problems: The knowledge gained from long experience in environmental testing sometimes permits solutions to space project problems. For example, thermal engineers designed a "temperature alarm" for the Atmosphere Explorer-C spacecraft. The device lets ground control know, in near real-time, when light-weight (low-mass) elements on experiment packages are in danger of being overheated by molecular bombardment. The danger arises when the spacecraft dips closer to the earth to sample the atmosphere in the range of 150 to 120 kilometers. A different type of problem was solved for the ATS-F spacecraft when a Quartz Crystal Microbalance Contamination Monitor was conceived and implemented. Its purpose is to monitor molecular condensibles at temperatures similar to a sensitive radiation cooler. Contamination originating from the spacecraft could seriously degrade the function of the cooler. Information provided by the monitor will enable ground control to make real-time decisions in managing operation of the spacecraft to avoid the contamination.

Modular Spacecraft Structure in Vibration Test



85-Foot Antennas at Rosman, NC



NASA Administrator Observes NASCOM Activities

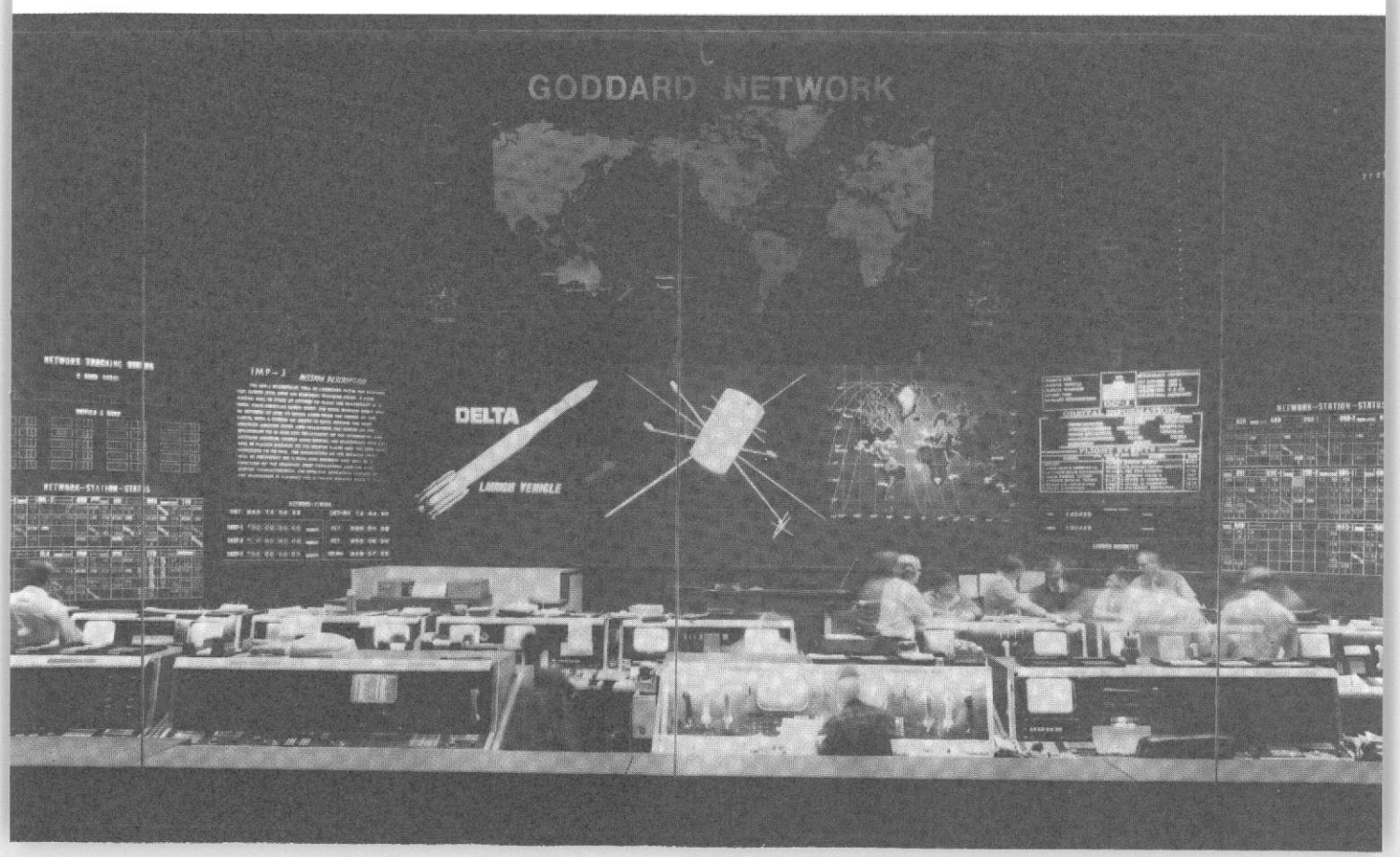
TRACKING AND DATA ACQUISITION

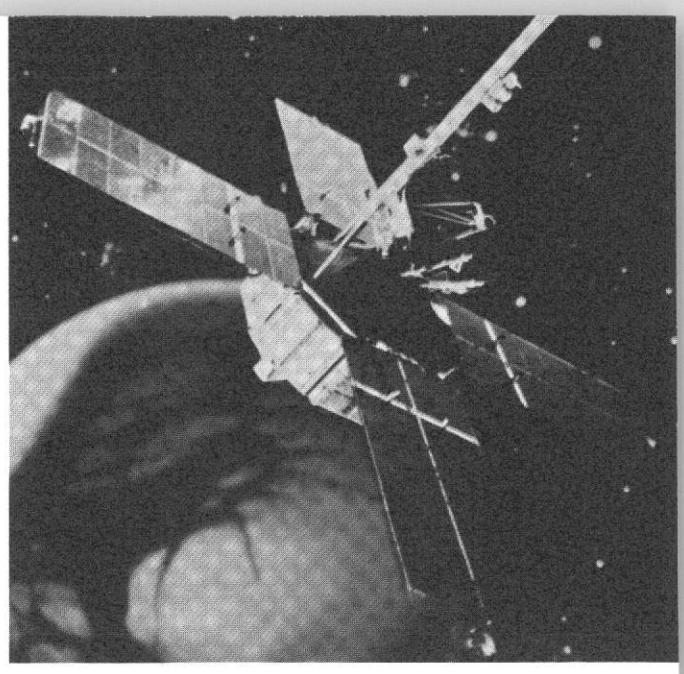
SPACEFLIGHT TRACKING AND DATA NETWORK

The Spaceflight Tracking and Data Network (STDN) is a worldwide complex of stations operated in direct support of scientific and applications satellites and the Manned Space Flight Program. The Network has the capability to determine the range, velocity, and location of the spacecraft, to transmit command data, to receive telemetry data, and, for manned flights, to provide voice communication between the ground stations and the spacecraft.

Although the number of launches has decreased over the years, the continuing support of vehicles launched in previous years and the increased complexity of the new spacecrafts make for a very heavy workload. During 1973 the Network supported the launch of 23 new spacecraft while continuing to support 51 others which were already in orbit. In accomplishing this task, 74,402 telemetry passes were received, 87,555 tracking operations were conducted, 76,089 hours of data were recorded, 60,517 command operations were scheduled, and over 1,300,000 commands were transmitted.

By far the biggest individual contributor to the workload was the Skylab Program. Skylab used only half of the network, but it used it day and night for 271 days. During that period, the over 2,800 people at the tracking stations with the 1,300 support personnel in the Baltimore-Washington area accounted for approximately 1,300 hours of tracking time and 3,240 hours of telemetry operations. This support resulted in over 1.7 trillion bits of data being received. Despite the complexity, the duration, and the repetitiveness experienced during the program, the network maintained its better than 99.9% record of delivering the data throughout Skylab.





MARINER 10 WIDEBAND COMMUNICATIONS

In January 1974, the NASA Mariner Venus/ Mercury 1973 (Mariner 10) spacecraft was scheduled to make a sweeping turn around the planet Venus and then speed onward to a rendezvous with the planet Mercury. Passing Mercury in late March at an altitude of barely 400 miles and a speed of over 25,000 miles per hour, Mariner 10 will continue on into an orbit around the sun. The primary science instruments on board Mariner 10 are two powerful television cameras for taking pictures of Venus and Mercury during the "fly-bys" of the planets. These pictures were to be transmitted by radio to earth over 90 million miles away. The very weak radio signals from Mariner 10 would be received by the 210-foot "dish" antennas of the Jet Propulsion Laboratory (JPL)-operated Deep Space Network located in Australia, Spain, and the Goldstone desert in California, amplified, and sent onward to JPL in Pasadena, California for picture enhancement and analysis.

The Goldstone station presented no significant problems; however, in Australia and Spain the pictures taken by Mariner 10 had to be re-transmitted to JPL. A unique communication system was designed by engineers of the NASA Communications Network (NASCOM) which would return the TV signals 23,000 miles back out into space, through an international communications satellite, back to earth in the United States, and then to JPL. Although special communication terminals had to be built to accommodate Mariner 10's unique TV signals, NASCOM's engineers determined that commercial telecommunications networks used for international telephone calls were capable of providing the "wideband data circuits" needed to transmit the pictures from Australia and Spain to the United States. The wideband circuits to be used were equivalent in information-carrying capacity (bandwidth) to the 12 telephone channels. Such circuits have been used in the United States since the early 1960s for computer-to-computer communications but had never before been extended outside the continental United States for the purpose of data transmission. Drawing upon experience gained in the United States and upon work being done by a United Nations technical group known as the International Telephone and Telegraph Consultative Committee, engineering personnel from NASCOM, from national and international telephone companies, and from the Australian and Spanish governments laid out their plans for the wideband circuits. It was determined that the entire wideband circuit bandwidth was not required for transmission of the TV pictures. Therefore, the terminal equipment designed by NASCOM and telephone company engineers provided for transmission of the TV pictures and at the same time provided four telephone-type channels. This arrangement would be very cost-effective since the same wideband circuit could now be shared by many users.

Although the activation of these first-of-a-kind international wideband circuits was not without difficulty and temporary setbacks, full cooperation among all organizations and people involved resulted in workable solutions to the most difficult technical and operational problems. The quality of picture transmission on these circuits has been excellent, and the same level of high performance is expected when Mariner 10 returns to the vicinity of Mercury in the fall of 1974.

MISSION OPERATIONS

The Mission and Data Operations facilities are a complex of eight mission operations control centers, data processing facilities and supporting systems for science and image data processing, and four large-scale digital computers providing operational support computing and analysis. These facilities are operated in direct support of scientific and applications satellites and provide the capability to command and control flight missions; receive, process, and deliver organized telemetry and correlative data to scientists and engineers; and perform computations for scheduling, orbit determination, attitude determination, and mission analysis. Although the number of launches has decreased in recent years, the continuing support to satellites has remained at a high level due to the increased complexity of the newer missions and more sophisticated and complex operations. During 1973 thirty-nine missions were supported on a continuing basis. In excess of 70,000 telemetry operations and 75,000 tracking operations were scheduled and conducted, which resulted in 4.4 million minutes of telemetry data. Fifty thousand real-time (on-line) operations were involved. The Atmospheric Explorer Operations Control Center was completed and has supported the launch of the AE-C mission. Overall this was the most dynamic and complex mission the facilities have supported. The Multi-Satellite Operations Control Center began in-orbit operations of the RAE-B and IMP-8 missions.

INFORMATION PROCESSING

The information processing activity at Goddard includes responsibility for the design, development, implementation, and operation of telemetry data processing systems which are used to support major projects. For example, the launch of the first Earth Resources Technology Satellite (ERTS-1) necessitated the establishment of a new image data processing capability. This facility is known as the NASA Data Processing Facility (NDPF) and has been in full production since the launch of ERTS-1. In the area of space sciences a dedicated facility was created especially for processing data received from the AE-C satellite.

ERTS Data Processing: The NASA Data Processing Facility (NDPF) is a job-oriented facility producing high quality data and distributing the data to user agencies. There are three types of processing performed in the NDPF; initial image generation, scene correcting, and digital processing.

Initial image generation results in the production of corrected 70 mm images of all video information recorded by the satellite. Included on the film images are annotation data regarding image location and time and gray scale for calibration. Initial radiometric and geometric corrections to the image video are also made. The 70 mm images thus produced are developed in the NDPF Photographic Processing Subsystem and inspected for quality and cloud cover. Images which meet the desires of the users are then enlarged, printed, and distributed to ERTS users.

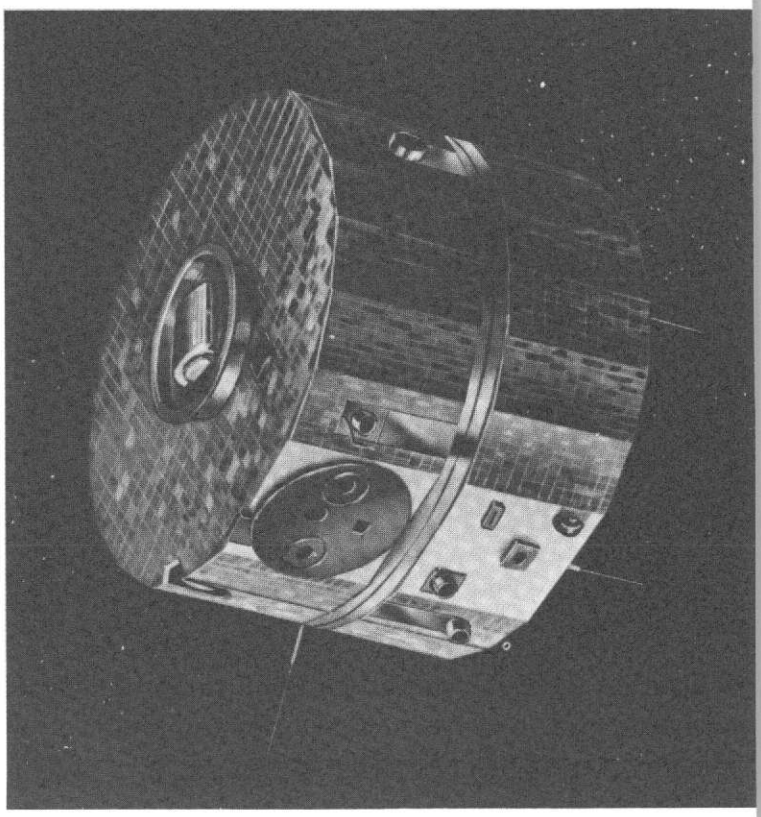
Scene correcting is performed on a small quantity of data specified by the users. The 70 mm images produced initially are processed by a hybrid system producing corrected film images on a 9½ inch film. This process removes geometric and radiometric distortions and performs precision location and scaling of the corrected video relative to map coordinates. Automated scene gridding and ground control point processing are used to perform these corrections.

Digital processing edits and formats data tapes produced during system corrected or scene corrected processing and outputs the data on computer-readable digital tapes for distribution to ERTS users. The capability may be provided to sample and analyze multispectral image signature data to provide enhanced imagery. All the foregoing processes are scheduled by work orders generated to match user requests against data received.

Space Science Data Processing: In the area of space sciences, a new concept in data processing and analysis was implemented with the Atmosphere Explorer-C (AE-C) launch. This dedicated facility consists in part of a Xerox Sigma 5 Input Processor computer which is connected by wire to a Xerox Sigma 9 central computer. A principal objective of this new facility is to allow the many scientists involved in this project rapid access to the data so as to interactively control the progress of the scientific investigation of the upper atmosphere.

The Sigma 5 Input Processor buffers the incoming telemetry data, inverts the reversed spacecraft tape recorder data, corrects the telemetry time to Greenwich Mean Time, checks and flags the quality of the data, and merges any overlapping data. The output of this operation is called time-smoothed data. The input processor builds tape files of time-smoothed data, as well as transferring the data over a serial high-speed line to the central computer. The data transferred to the central computer over the high-speed line are put into a direct-access file for immediate use.

The Xerox Sigma 9 central computer interfaces with 14 terminals through a Xerox Sigma 3 and services about forty investigators and co-investigators. The Sigma 9 serves as the main repository for the input telemetry data, the results of the orbit attitude processing, the results of the investigator's analyses, and the history of the spacecraft and operations control center actions. The primary functions of the computer facility are to process, reduce, and analyze data for the experimenters. The volume of data to be processed is 53 x 106 telemetry data words per day. It is expected that the Sigma 9 and Sigma 3 will be operated 24 hours a day, 7 days a week to keep pace with this high volume of data.



MISSION OPERATIONS COMPUTING SUPPORT

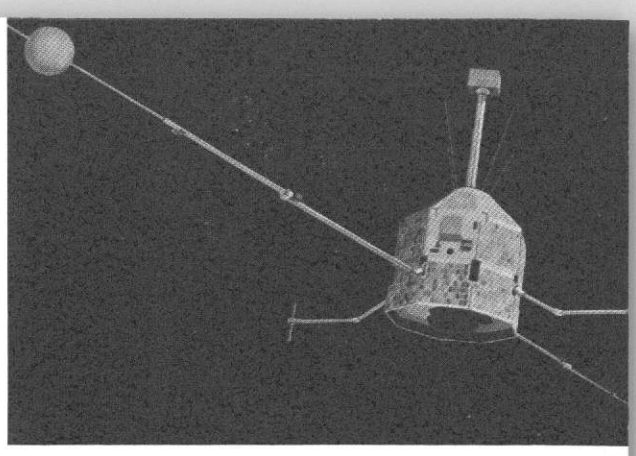
Flight Dynamics Activities: The implementation of the Flight Dynamics System (FDS) concept was achieved in 1973 with the successful support of the Radio Astronomy Explorer (RAE-B) which was launched June 10 and inserted into lunar orbit June 15. This interactive, intercommunicating system of orbit determination, attitude determination and control, and trajectory maneuver strategy software was designed to operate on a single computer with the use of on-line graphics to ensure the response required to support those missions having critical maneuvers. The Atmosphere Explorer (AE-C) spacecraft, launched December 16, was also successfully supported with a Flight Dynamics System. An added feature of the AE-C support was the

near real-time monitoring of orbit maneuvers with the use of an on-board accelerometer package which also functioned as a scientific instrument. The Interplanetary Monitoring Platform (IMP-J) spacecraft, launched on October 25, presented a challenging problem in in-flight mission analysis—that of determining the appropriate time and attitude to fire the apogee motor to achieve an orbit having desired characteristics and being phased 180 degrees from IMP-H, launched one year earlier. A firing strategy was planned and executed that ensured a phasing between IMP-H and IMP-J of about 180 degrees for over one year. In addition to the above spacecraft, attitude support was provided for OSO, SAS and SSS satellites, and synchronous satellite maneuver and control support continued for the Applications Technology Satellites (ATS-1, 3 and 5).

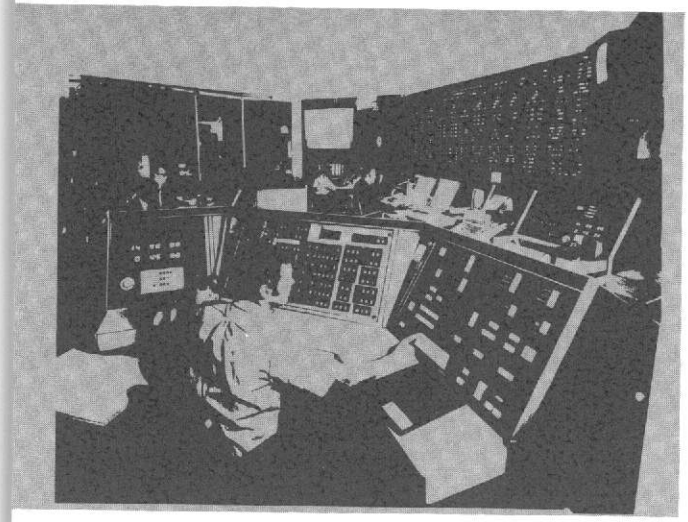
Computer Operations: Mission operations support efforts during the year have been towards improved efficiency and increased programmer effectiveness. Both hardware and software computer monitors have been used, and we are approaching a capability to establish computer program profiles which will yield considerable information about computer workloads and computer program resource utilization.

A number of satellite launch and in-orbit activities were supported during the year with the most complex being provided to Atmospheric Explorer (AE-C). This satellite, launched in December, required support from two 360/75s, the 360/65, and the 360/95.

The mission operations facility's largest computer is the 360/95 which supports approximately 16,000 jobs each month. Remote terminal activities are supported involving more than 50 typewriter terminals and approximately eight RJE (Remote Job Entry) printing and card handling terminals. Graphics support is provided through three IBM 2250 and eight IBM 2260 CRT terminals.



Largely as a consequence of the complex AE-C requirements, new transmission controllers were installed on both the 360/95 and one of the 360/75 computers. This was necessary in order to increase the data bandwidth and the number of communications lines to transfer that data from control centers into the 360 computers. Installation and implementation of these transmission controllers disclosed a number of problems related to installation of plug-compatible equipment in a near-total IBM installation. The transmission controllers are now working acceptably and are providing the greater-bandwidth multi-line capability required.



ADVANCED PLANNING AND DEVELOPMENTS

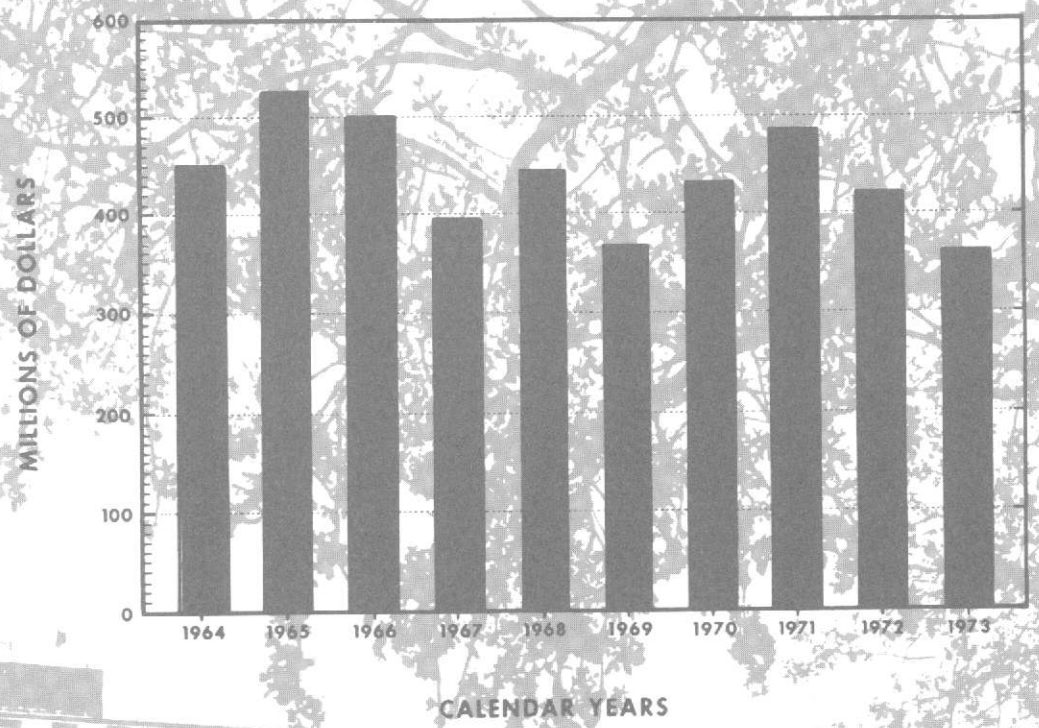
Network Utilization and Shuttle Studies 1979-1990: Advanced system planning is underway to formulate and develop comparative models of network support capabilities and network resources that will be required to provide ground support of shuttle and shuttle-launched payloads in the 1979-1990 time frame. At this time, it appears the network resources would include a Tracking and Data Relay Satellite (TDRS) system plus 8 to 11 ground stations for supporting shuttle orbiter, sortie labs, space tugs, and payloads injected into synchronous orbit and beyond or orbits above 350 n mi with the space tug, as well as payloads launched via conventional Delta boosters during the interim phase-over period to shuttle launches. Planning activities include identification of system capabilities, operational philosophy, and new technology associated with the new generation of spacecraft and shuttle-launched vehicles in sufficient detail to define hardware system requirements for the ground-support network. Support requirements are being investigated for future manned and unmanned missions such as shuttle, large space telescope, space stations/platforms, TDRS, earth observation satellite, high energy astronomy observatory, orbiting solar observatory, earth resources technology satellite, synchronous earth observational satellite, etc.

Wideband Data Transmission Systems Ground Antenna: To prepare for future advanced spacecraft systems, techniques and components are under development which will yield high efficiency antenna systems, feed systems, and low-noise premamplifiers. In addition, refinements are underway in the area of dichroic subreflector techniques which permit simultaneous and efficient operation of an antenna at different frequencies without degradation of overall performance or flexibility.

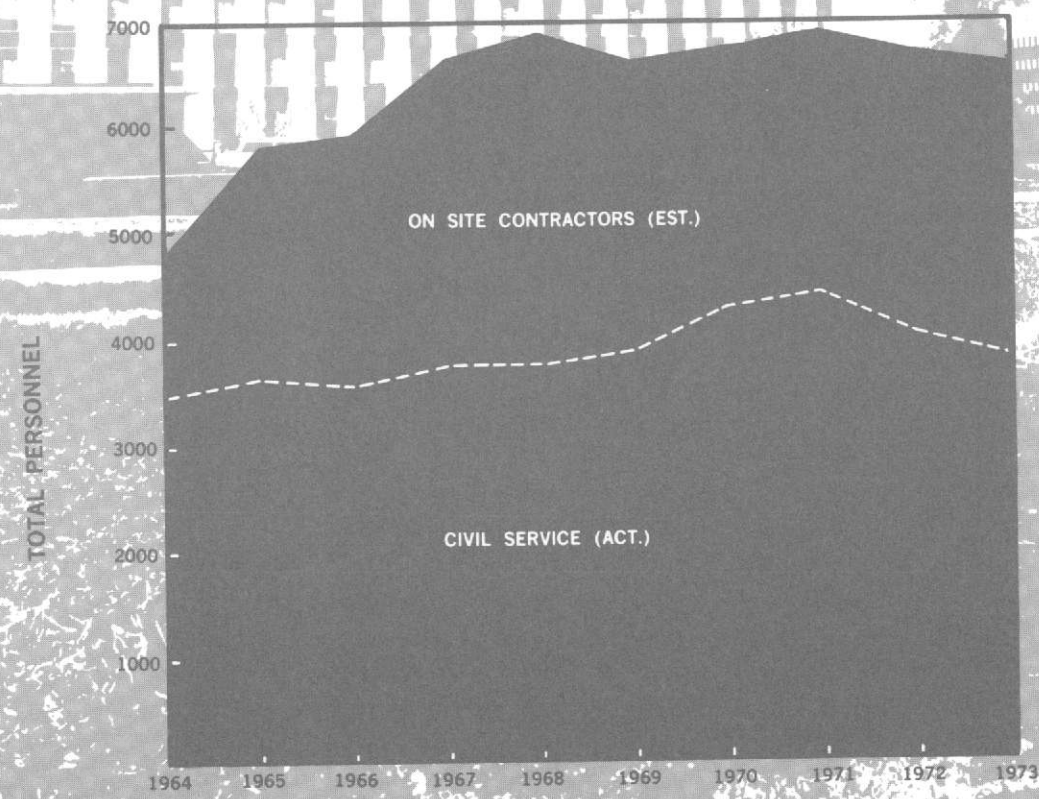
These advancements are necessary because future spacecraft systems will transmit data to the ground at rates much higher than that of current operational systems. The Earth Observation Satellite (EOS) will transmit high resolution color TV either directly to a ground station or via a Tracking and Data Relay Satellite (TDRS). The TDRS will transmit signals from EOS and other satellites which require total TDRS bandwidths approaching 1 GHz. Existing NASA ground stations are not equipped for such data rates.

Automatic Computer Program Documentation: Work is progressing for the implementation of an automatic system for computer program documentation. This system will produce timely, up-to-date documentation at relatively low cost. Initially the system will be designed to accept FORTRAN, COBOL, PL/1, and Assembler languages. There will be no restrictions inherent to the design which will prevent it from being used to document other languages. It is being designed to operate on the IBM 360 with expansion to the UNIVAC 1108 and CDC 6600 computer systems. All programs being written are in a machine-independent language so that they can easily be moved from computer to computer. For the programmers who write programs in their own unique way, the automated system will be able to produce documentation such as detailed, detailed-suppressed, global flow charts, data layouts, overlay descriptions, etc. For programs developed outside this system, it will be fairly easy to retro-fit the program into the system for documentation maintenance.

PROCUREMENT OBLIGATIONS



PERSONNEL



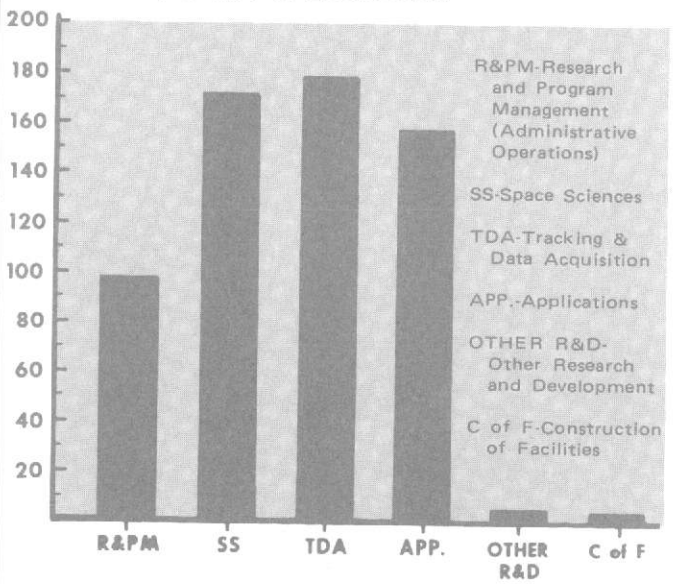
ADMINISTRATIVE OPERATIONS

FINANCIAL MANAGEMENT AND PROCUREMENT

In 1973 a new financial management system was implemented within NASA. A good deal of Goddard's budgetary activity centered around Center compliance with the requirements of the new Institutional Management System, the principal goals of which are:

- To identify and recognize the total resources being used in the conduct of project (direct) activities.
- To provide operational activities with sufficient and timely funding to permit efficient and effective management of institutional activities.
- To provide all levels of management with the budgetary visibility necessary for prudent decision making.

FY 1973 BUDGET



Goddard's Fiscal Year 1973 R&D budget was $509,500,000 which includes $35,000,000 of reimbursible costs. Funds for administrative operations were $100,500,000, including $3,300,000 for new construction and $1,500,000 in reimbursibles.

In 1973 procurement activities involved the annual execution of over 25,000 contracts with obligations approximating $360 million.

Major prime contracts awarded included:

- A contract for On-Site Data Processing Services awarded to a joint venture — Computer Sciences Corporation, Technicolor Graphics, and DP Associates, valued at $23.7 million.
- A contract for Maintenance and Operation of the GSFC Mission Operations Center, Project Operations Control Center, Goddard Optical Research Facility, and Mission Support Group, awarded to the RCA Service Company, valued at $21.6 million.
- A contract for Maintenance and Operation of the Spaceflight Tracking and Data Network (STDN) to the Bendix Field Engineering Corporation, valued at $38.1 million.
- Forty-eight contracts for Off-Site Engineering Support Services to twenty-four companies, valued in the aggregate of $7.0 million.

While the above awards are regarded with a sense of accomplishment, Goddard is equally concerned with the placement of awards with small business firms and, more particularly, minority business enterprises. Special effort in these areas resulted in the placement of $25.5 million with small business firms during CY 1973, including $1.0 million with minority businesses.

Grants and contracts valued at $13.0 million were also placed with universities in acknowledgement of the vital role they play in the accomplishment of basic and applied research.

LIBRARY IMPROVEMENTS

Over the years Goddard's technical library has grown with the Center to provide services necessary to support research and management requirements. With the passage of time a sizable portion of the library book collection had become dated, and it was necessary to selectively dispose of these items to make room for newer, more current materials. This was done in early June and, at the same time, a new, automated circulation control system was started. The new system provides accurate, positive circulation records; generates special usage reports; and automatically issues overdue notices. Future system expansion plans include an automated reserve system.

MANPOWER HIGHLIGHTS

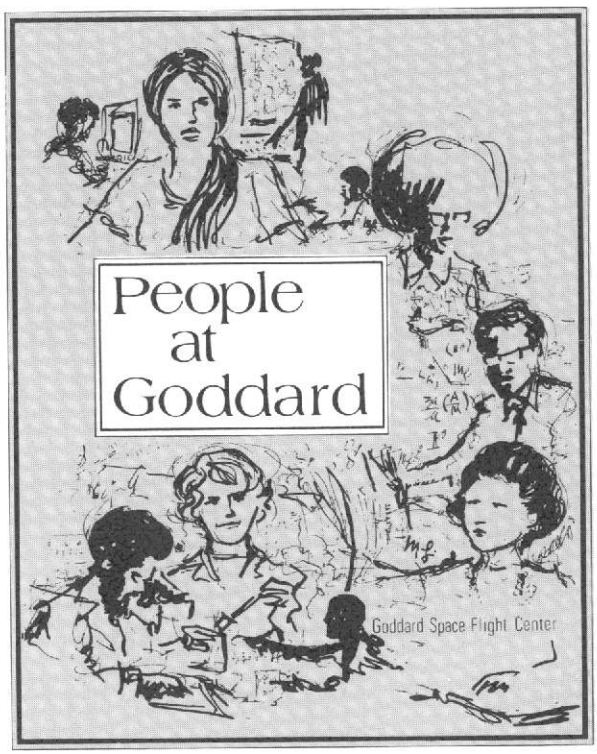
The Goddard Space Flight Center began calendar year 1973 with a complement of 4,086 Civil Service employees, with promotions and hirings frozen, and facing a requirement to reduce the personnel complement to 3,966 by June 30 with an average grade not exceeding 11.0048. Employees were aware of the fact that a reduction in force was necessary in the first six months of 1973 because it would be impossible to reach the assigned average grade by attrition and because reaching our assigned ceiling by attrition would result in an unbalanced skill mix.

Maximum effort during the first half of the year was devoted to preparing for and conducting a work force adjustment which culminated on May 18, 1973 with 242 employees affected: 86 were involuntarily separated, 84 changed to a lower grade, 47 reassigned at the same grade, and 25 reassigned while in a RIF status. In order to provide maximum assistance to employees affected by the work force adjustment, a dynamic out-placement program was conducted. The program was an outstanding success with 84 employees placed in positions in other activities out of a total of 95 who registered for assistance.

During the year we hired 175 employees and were able to resume a limited promotion program which resulted in 314 employees being promoted. We ended the year with a complement of 3,801 Civil Service employees, 165 less than our authorized strength.

Equal Employment Opportunity was a topic of special emphasis by management throughout the year, with significant efforts exerted to improve our posture in this area. Approximately 20 percent of the new hires in 1973 were minority employees, and approximately 23 percent of the professional hires were women. Our various summer and special programs provided many opportunities to needy youth, especially those of the minority races. The year 1973 came to a close with Center management and the personnel staff determined to make 1974 a banner year in the administration of Equal Employment Opportunity.

Training support was provided to approximately 2,000 of the Center's employees, totaling over 3,000 enrollments in 1973.



Twenty-six employees received college degrees with over 50 percent financial support from the Center. Educational instruction was given at local universities, on Center, and at other government and commercial institutions.

Besides offering core courses such as supervisory and safety training, which are required on a continuing basis, new state-of-the-art courses, such as metrication and remote sensing technology, were developed which relate to new agency programs. Self-instruction by means of cassette tape and video tape equipment was on the upswing in the areas of language, secretarial, and scientific courses.

As the year ended, expansion of the Center's formal Upward Mobility Program was on the horizon along with increased emphasis on training related to equal employment opportunity and other personnel management programs for upgrading the utilization of the Center population's potential.

PATENT ACTIVITY

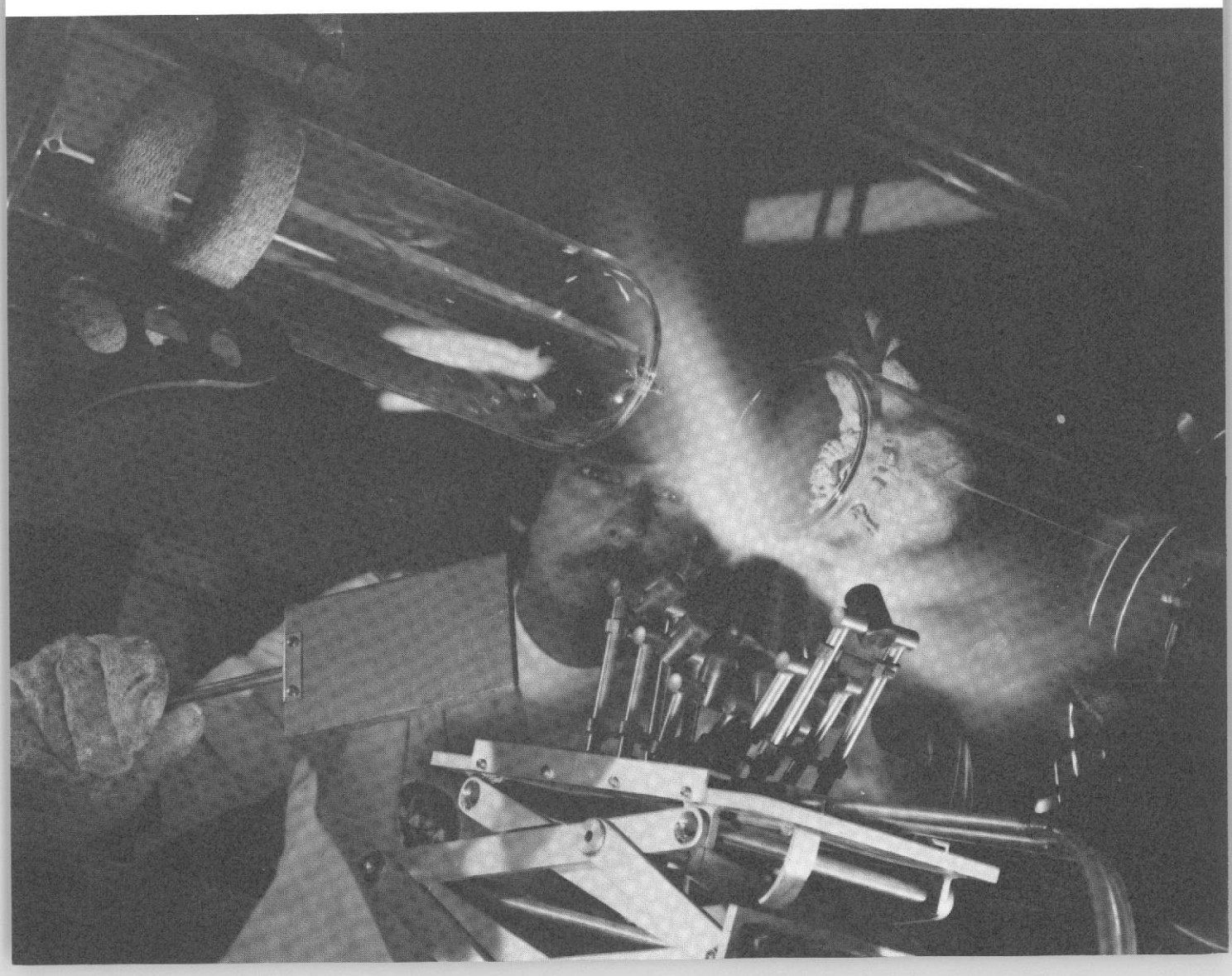
During the year, 28 patents were issued on inventions arising out of Goddard activities. Of these, 17 were for inventions made by GSFC employees and 11 were for GSFC contractor employees. In the same period, 22 new patent applications were filed in the U.S. Patent Office. These inventions relate to items having significant utility in space activities, with many also having potential for commercial applications. Consequently, all filed

patent applications are widely publicized and made available for commercialization under the NASA patent licensing program. There are currently 51 non-exclusive licenses for commercial development of 19 GSFC inventions, two royalty-bearing exclusive licenses in foreign countries, and three exclusive domestic licenses under evaluation.

Typical of the diversity of patent applications filed for GSFC employees during the past year were inventions relating to a new all-digital phase-locked loop; improvements in heat pipe structures; and a high-gain narrow beamwidth antenna. Also, an invention disclosure was received and a patent application is under preparation for exciting new computer concepts relating to two dimensional radiant energy array computers and computing devices.

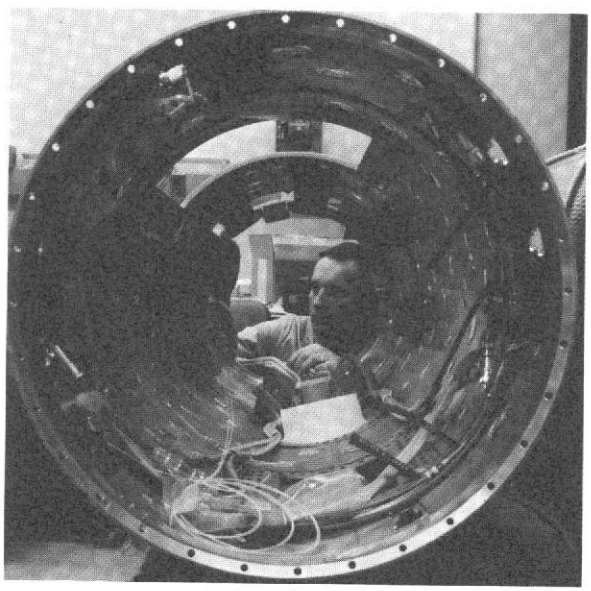
Digital Phase-Locked Loop: This invention relates to an all-digital phase-locked loop which obviates the usual use of analog devices such as low-pass filters, analog integrators, and voltage-controlled oscillators, thereby providing a very precise loop which is free from drift, nonlinearity, and other difficulties associated with analog devices. The phase-locked loop of the invention is a device of general commercial application.

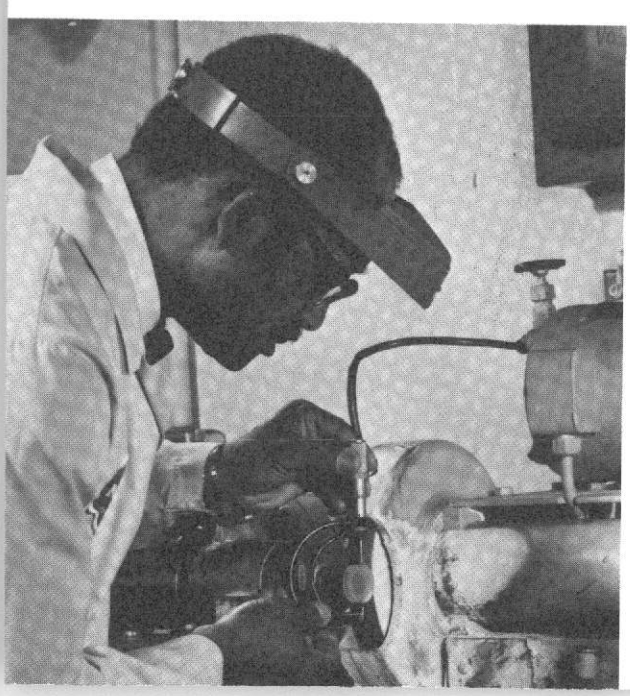
Structural Heat Pipe: This invention broadly relates to thermal insulation systems and particularly concerns a combination structural reinforcing element for a spacecraft wall and heat transfer member by which heat leakage through an outer insulation blanket of the spacecraft is rapidly drawn off to reduce thermal gradients in the spacecraft wall.



The invention incorporates a heat pipe which is fastened so that it supports an outer thermal insulation blanket on one side, while the opposite side acts as a structural reinforcing member for the spacecraft skin. As heat is leaked into the system through a penetration in the thermal insulating blanket, the heat energy reaches the heat pipe and is drawn off to colder portions of the structure, thus eliminating or substantially reducing temperature gradients in the spacecraft wall.

By utilizing the heat pipe, it is no longer necessary to provide a separate structural support element between the thermal blanket and the spacecraft wall. The invention combines the functions of these two typical elements and improves the function in that better performance is achieved with respect to the reduction of thermal gradients in the spacecraft with a marked reduction in cost and weight. The invention further has applicability to ground-based insulation systems such as would be utilized with cryogenic containers.





Dish Antenna Having Switchable Beamwidth: This invention involves the provision of high-gain, narrow-beamwidth dish antennas with a selective low-gain, wide-beamwidth mode of operation for effecting acquisition. The invention is particularly relevant to the proposed Tracking and Data Relay Satellites for communicating with Earth Observation Satellites.

The invention has two main embodiments, both of which involve the excitation of the main dish from a feed via a truncated subreflector in the wide-beamwidth mode. One embodiment is directed to a Cassegrain antenna configuration in which an annular portion of a hyperbolic subreflector is selectively translated or mechanically retracted to an "out of focus" position leaving a truncated subreflector in the form of a fixed central portion. Because of a one-to-one mapping of radiation on the subreflector and radiation on the main parabolic dish, an outer annular portion of the main dish is not excited when the subreflector is truncated, reducing the effective area of the main dish, and consequently increasing the antenna beamwidth. The second embodiment is directed to a Gregorian antenna configuration with two available feeds. One feed directly excites the entire main dish for narrow beamwidth, and the second feed excites only the central region of the main dish via a truncated ellipsoid subreflector. Beamwidth switching in this embodiment is accomplished by electrically selecting either feed.

Novelty is believed to reside in the provision of means for selectively exciting the entire main dish or only its central region, wherein a truncated subreflector is used for exciting only the central region.

EDUCATIONAL PROGRAMS

With the implementation of the Space Act in 1958 it was decided that the education community composed of teachers and students was a prime audience for carrying out Section 203 (a) (3) of the Space Act of 1958 as amended (42 U.S.C.) 2473 (a) (3), which reads: *"provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."*

Starting about 1959 each major field center, over a period of a few years, established an Education Office to respond to the educational community of local geographic areas. Goddard was the first to establish this function in 1963 with responsibility for the District of Columbia and eleven northeastern states (until ERC closed it was only D.C. and five states). The area contains approximately one-fourth of the total school population of the U.S.A.

A careful and conservative estimate reveals that at least 400,000 students, teachers and the general public had direct contact with Goddard during 1973 in these program and service categories. This number does not include information on Goddard research and development programs obtained through television programs (for example, the Kohoutek one-hour special was broadcast two or more times over 182 PBS stations) and radio or news articles in local communities where NASA educational activities were taking place.

Calendar year 1973 was a busy and exciting year in providing programs and services to the educational community. Brief statistical summaries of the primary program and service categories follow.

Aerospace Workshops for Teachers: These are full-day sessions of five to ten days where aerospace instruction is provided by Spacemobile space science education specialists. When on college campuses Spacemobile personnel are also scheduled for presentations in the regular science education classes.

June 18-29—Appalachia Intermediate Unit #8, Pennsylvania State University, Altoona Campus and Bedford, Blair, Cambria and Somerset Counties

July 16-August 3—New York State University, New Paltz, New York

July 23-27—Fitchburg State College, Fitchburg, Massachusetts

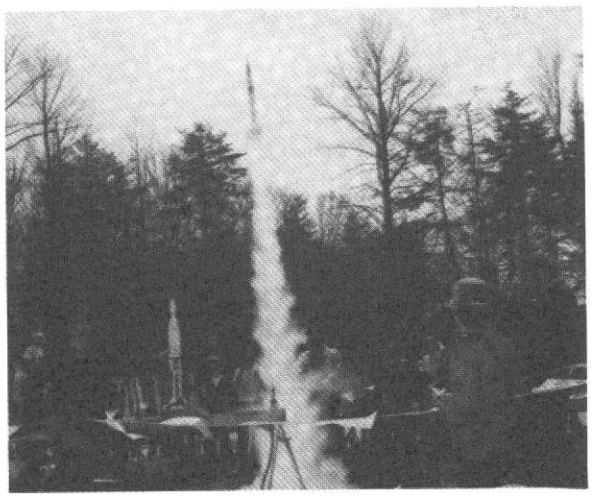
July 23-August 10—Towson State College, Towson, Maryland

July 23-August 10—C.W. Post College, Greenvale, New York

July 23-August 31—Industrial Arts Department, Millersville State College, Millersville, Pennsylvania

July 30-August 10—Intermediate Unit #1, Fayette, Greene, and Washington Counties, Pennsylvania

August 20-31—Stamford, Connecticut Public Schools



Community Involvement Programs: These programs bring together NASA scientists, occasionally astronauts, Spacemobile personnel for student programs and teacher workshops, NASA exhibits and local community resources (people and exhibits) in an in-depth experience with space exploration and high technology. Programs are planned with top level school officials and community civic leadership groups. Over 50,000 people were in direct contact with the space program in 1973 through programs in their own communities as listed below:

March 19-23—Gateway Regional School District, Huntington, Massachusetts

May 1-9—Newark, New Jersey Space Week
May 13-18—Rochester, New York and Nine Surrounding Counties
November 5-9—Potsdam, New York Area
December 3-7—Manchester, Connecticut Area

Conferences:

Northeast Regional Conference of the Massachusetts Council for the Social Studies, April 4-7

National Conference for Spacemobile Personnel on Theme of ERTS at GSFC, June 4-8

New York State Educational Communications Association Convention at Grossingers, New York, November 6-9 (approximately 800 attendees)

Educational Publications and Audio-Visual Materials: Produced "Comet Kohoutek" publication for teachers. Distributed 50,000 copies nationally to State Departments of Education, libraries, planetariums and some 30,000 educators on NASA Headquarters Educational Programs Division mailing list.

Produced "Comet Viewers Guide," a four-page brochure, and distributed 100,000 to Public Broadcasting Stations, which carried the Maryland PBS produced one-hour special on the comet, for distribution to their viewers.

Proposed and provided technical assistance for a film strip on ERTS which was produced by the Northeastern Environmental Educational Development Consortium which was funded by a U.S. Office of Education grant to implement environmental awareness activities for students and teachers. Produced by George C. Atamian, Talcott Mountain Science Center, Avon, Connecticut.

Educational Television:

March 21—"Kids News Conference," WJZ Channel 13, Baltimore

October—Proposed through Connecticut Department of Education for production by Connecticut ETV of a program on ERTS. Funds obtained by Department of Education from Northeastern Consortium for Environmental Education. Thirty-minute program due for completion summer 1974.

December—"The Coming of a Comet," a one-hour special produced by the Maryland Public Broadcasting System featuring GSFC scientists on camera. One hundred eighty-two PBS stations across the country carried the program at least twice and some used it four times.

School Curriculum Development Consultations at GSFC:

D.C. Schools Programs for Handicapped

P.G. County Career Education Advisory Committee.

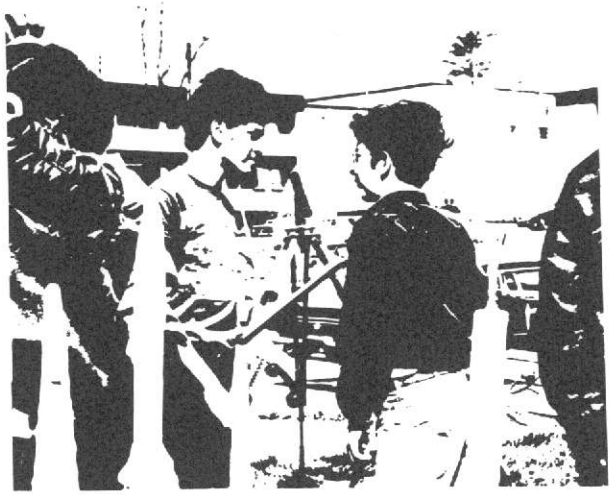
Program on "Utilization of Community Resources" to P.G. County Career Development Workshop.

Humanities consultant for Rhode Island State Department of Education visited GSFC for assistance in using ERTS imagery in developing activities for students and teachers working on the Narragansett Bay Project.

Spacemobile School Visit Program:

January—December 1973

Type of Audience	Number of Programs	Attendance
Elementary	389	119,400
Junior High	180	63,329
Senior High	107	50,290
College	7	900
Classes Visited	703	25,312
Civic Groups	22	2,565
Teacher Workshops	51	1,158
Special Programs	86	9,858
Total	1,545	272,812



Youth Programs:

Programs for Economically Deprived

Montgomery County Title I Schools, Spring '73—One-day program in each of 18 schools.

Stevens Institute of Technology, Hoboken, New Jersey, July 12—One-day program for underpriviledged high school students in New York and Newark.

Casita Maria Settlement House, Bronx, New York, July 26—One day program on Skylab and ERTS.

Camp Torah Vodaath, Highland, New York—One-day program on aeronautics.

Presidential Classroom for Young Americans at GSFC

Student Programs, Spring '73—Six groups, 1400 students, 59 states and 11 foreign countries.

Teacher Programs, Summer '73—Three groups, 200 teachers

Prince George's County Vocational Development Program

Twenty to twenty-five local students worked half days at Goddard during spring and fall semesters of 1973 learning specific job skills. Program funded by P.G. County Board of Education.

Summer Program for County Vocational Development Program Students

Twenty students worked 25 hours per week in specially selected vocational areas. Program co-sponsored by Board of Education and Neighborhood Youth Corps.

Elementary School Astronomy Education Project

Nine 5th and 6th graders spent 2 afternoons per week for six weeks in the GSFC planetarium learning basic astronomy concepts in order to be leaders in student astronomy projects back at school.

Pre-Professional Career Work-Study Program

Thirty local students spent two afternoons per week for six weeks working with professionals in the areas of computer science, physical science, and engineering.

Neighborhood Youth Corps-2 Program for High School Drop-Outs

Twelve students worked several hours each day in computer operation, audio-visual technology, and drafting during spring and fall semesters 1973.

Student Skylab IV Prelaunch Seminar at Daytona Beach and Kennedy Space Center, November 7-10

Four hundred students from the northeast who were bused to Florida at their own expense participated in this seminar and 10 Goddard scientists and engineers were consultants or presentors. Even though Skylab IV was postponed one week the students had a rare educational experience.

NASA Science Fair Awards Program

Coordinated the selection of space-related science fair projects in 20 regional and state science fairs (two of these in Canada), provided certificates to five student winners in each fair, and conducted special one-day program for winners and their parents at GSFC during summer of 1973. Students and parents from seven states of the region attended.

Career Day Programs

Coordinated the appearance of a large number of Goddard personnel in secondary schools of the immediate area to talk with students about careers.

GODDARD SPACE FLIGHT CENTER MANAGEMENT COUNCIL

J. F. Clark, *Director*

D. P. Hearth, *Deputy Director*
L. H. Meredith, *Assistant Director*
M. J. Vaccaro, *Associate Deputy Director for Management*
S. W. Keller, *Director of Administration and Management*
H. E. LaGow, *Director of Systems Reliability*
R. N. Lindley, *Director of Projects*
A. G. Ferris, *Director of Mission and Data Operations*
G. F. Pieper, *Director of Sciences*
J. Purcell, *Director of Engineering*
T. Roberts, *Director of Networks*
W. Nordberg, *Director of Applications*